Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

984B
466

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1493

Washington, D. C. ▼ June, 1927

LIBRARY
RECEIVED
★ AUG 8 1927 ★
U. S. Department of Agriculture

TIMBER GROWING AND LOGGING PRACTICE IN THE DOUGLAS FIR REGION

MEASURES NECESSARY TO KEEP FOREST LAND PRODUCTIVE AND TO PRODUCE FULL TIMBER CROPS

By

THORNTON T. MUNGER, Director
Pacific Northwest Forest Experiment Station, Forest Service

Introduction by

W. B. GREELEY, Forester, Forest Service

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON
1927

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1493

Washington, D. C. June, 1927

TIMBER GROWING AND LOGGING PRACTICE IN THE DOUGLAS FIR REGION

By THORNTON T. MUNGER, *Director Pacific Northwest Forest Experiment Station, Forest Service*

Introduction by W. B. GREELEY, *Forester, Forest Service*

CONTENTS

	Page
Introduction	1
General situation in the Douglas fir region	5
The forest and forest types	5
The Douglas fir type proper	6
The fog-belt type	6
The upper-slope types	7
Factors affecting natural reforestation in the Douglas fir type	7
Seed production	8
Seed dissemination	8
Seed storage in the duff	8
Slash burning	9
Importance of prompt slash disposal	10
The place of single seed trees in Douglas fir reforestation	11
Reforestation factors in the fog belt	12
Logging as it affects reforestation	13
Status of reforestation under present practices	14
Minimum measures to keep forest land productive	15
Fire control the paramount consideration	15
Care of the virgin forest	16
Treatment of the forest and cut-over land during logging	16
Direct protection	17
Fireproofing cut-over land, or indirect protection	19
Prompt and careful slash burning in the Douglas fir type	20
Slash disposal in the fog belt	22
Seed supply	23
Treatment of the new forest crop after logging	24
Protection from fire	24
Grazing of reforesting, logged-off land	24
Minimum measures to keep forest land productive—Continued.	
Regional cooperative system of forest protection	25
The present system	25
Present expenditures for protection	25
The present fire record	26
Causes of fires	26
Needed modifications in the protective system	27
Cut-over land and young growth should be protected for their own sake	27
The protective system should be gauged to fit the fire hazard	27
Preventive work should be strengthened	28
More money for general protection	29
Modification of State fire laws	30
Returns and costs of minimum measures	30
Expected future yields	30
Costs	32
Supplementary measures for intensive timber growing	34
Technical plan of management	36
Direct protection against fire	36
Indirect protection against fire, or fireproofing land	37
Provision for assured reforestation through seed trees or planting	38
Leaving adequate seed trees	38
Planting the failed areas	39
Reclaiming denuded lands by planting	40
Control of mixture of species in the new crop	40
Thinning the growing crop	40

INTRODUCTION

Forestry in the United States is no longer merely a theory or a subject for discussion; it has gotten down to concrete things in the woods. Nor is the growing of timber confined to public lands; it is gradually making headway on land in private ownership. It is becoming an art of land management, expressed in practical measures for protecting forest growth from fire and other destructive agencies,

for logging timber so as to produce a new crop of wood, and for planting forest trees on cut-over or denuded areas. The value of timber along with other economic considerations, is causing landowners more and more widely to study the possibility of profitable reforestation. These developments have created a general demand for information on the timber-growing methods which are adapted to the various types of forest growth in the United States and on what these methods will cost.

Timber culture, like the growing of farm crops, is necessarily governed in any country by the soil and climate, by the requirements of the native forest trees, and by the national economic circumstances. Lessons may be drawn from the experience of other countries, as the United States has drawn upon the forestry practice of Europe; but profitable methods of growing timber, particularly under the wide range of forest types and economic conditions in the United States, can be evolved only from our own experience and investigation, region by region. Hence, to meet the demand for information on practical ways and means of growing timber profitably in the various parts of the United States, it is important that the results of our own experience and investigation to date be brought together and set forth in the clearest possible way.

This the Forest Service has attempted to do in a series of bulletins dealing with the 12 principal forest regions of the United States. The information presented has been gathered from many different sources, including the experience, as far as it was obtainable, of landowners who have engaged in reforestation. An effort has been made to bring together all that any agency has yet learned or demonstrated about the growing of timber in the United States, and the results have been verified as far as possible by consultation with the forest industries, State foresters, and forest schools. These publications thus undertake to set forth in a simple form what are believed to be the soundest methods of reforestation as yet developed in our common experience and study in the United States.

Necessarily the Forest Service claims no finality for the measures proposed. Timber growing in every country has come about through a gradual evolution in industrial methods and the use of land. All too little is yet known of the best methods of growing timber under American conditions. As time goes on, research and practical experience will add greatly to the success and certainty of the measures carried out in our woods, just as American agriculture has steadily become more highly developed, or just as our manufacturing processes have been perfected through experience and study. But we know enough about growing timber now in the forest regions of the United States to go right ahead. Believing that the forest landowners of the United States are now ready to engage in timber growing on a large scale, the Forest Service has endeavored to place before them in concise terms the best suggestions and guides which the experience of this country to date affords.

In these publications the measures proposed for a particular forest region have been arranged in two general groups. The first includes the first steps, or the minimum measures based on local physical conditions, that are needed to prevent timber-bearing land from becoming barren. These measures, in which the prevention of fire is of outstanding importance, represent, broadly speaking, the least

that must be done and the lowest cost that must be incurred to keep forest lands reasonably productive. While influenced in some cases by the economic conditions in the region, they have been worked out primarily from the standpoint of the landowner who may not be ready to engage in real timber culture but who wishes to prevent cut-over tracts unsuitable for any purpose except timber growing from becoming a liability on his hands. Except within certain limitations, which are discussed in dealing with particular regions, the Forest Service believes that these first steps or minimum measures should be speedily applied to all of the forest lands in the United States. And the Forest Service believes that public policy should encourage their universal application in such ways as protection from fire and the adjustment of forest taxation to the business of timber growing.

The second group of proposed measures constitutes what may be called the desirable forestry practice in the region concerned as far as our knowledge and experience to date enable us to determine it. These measures are designed to grow reasonably complete crops of the more valuable timber trees, making full use of the real productive capacity of the land. The recommendations are addressed primarily to the landowner who wishes to use his property up to its full earning power for timber culture. It is impossible to frame any general set of measures of this character that are adapted to the individual needs of particular holdings or industrial establishments. This is true particularly of forest regions like the Northeastern States, which include a great variety of local situations both in the types of growth and in economic circumstances. Hence, in presenting this group of suggested measures, the Forest Service has attempted only to draw the broad outlines of the more general and fundamental things, with illustrative methods of forest practice. The details of intensive forestry, like the details of intensive agriculture or engineering, call for expert survey in working out the plans and methods best adapted to a particular tract of land or a particular business. One of the most important features of expert planning for the management of a particular forest property or for a supply of raw material for a particular forest industry is to devise, not simply woods operations that will produce full crops of timber, but also a scheme of logging that will afford a continuous yield of products desired, in order that sustained earnings may be realized or a sustained supply of raw material made available.

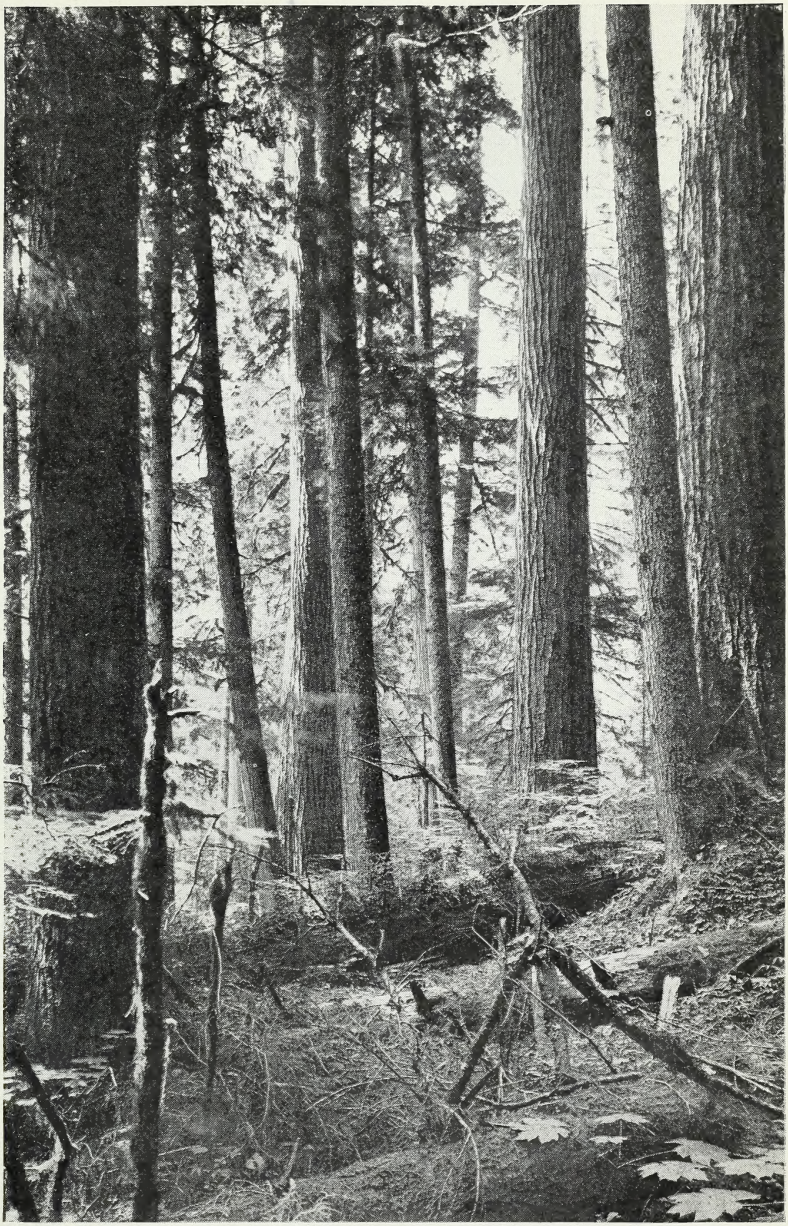
In some cases it is not practicable to draw a hard and fast line between the first steps that will maintain some degree of productiveness on forest land and the more intensive measures that will bring the quantity and quality of wood produced up more nearly to an ideal management. Gradations between the two general groups of measures are inevitable. The Forest Service has not attempted, therefore, to deal with the two general types of forest practice as wholly separate and distinct, but has rather endeavored to present a common-sense and practical résumé of the various steps in timber growing in the form that will be most helpful to the man in the woods. The bulletins have been written for the landowner and the lumberman rather than for the technical forester. Their purpose is to put the main ideas into the most useful form, considering the special needs and problems of each region, for aiding

the man to whom timber growing is a concrete business and logging problem. At the same time it is hoped that they will have a value for the everyday reader who is interested in forestry as an important phase of land use in the United States and in the public policies designed to bring forestry about.

It is impossible for publications necessarily dealing in broad terms with the conditions existing over large regions to attempt any brass-tack conclusions on the cost and returns of timber growing. The approximate cost of the measures advocated is indicated as far as practicable, and the extent to which they may be of benefit in connection with logging operations, but with no attempt to segregate the items chargeable to harvesting one crop of timber from those which should be regarded as invested in a following crop. Conservative estimates of the future yields of timber that may be expected under the various practices recommended are given where the facts available appear to warrant them; but no forecasts of the profits to be derived from commercial reforestation are attempted. The financial aspects of forestry can not be dealt with in general terms. Here, again, expert advice must deal with the situation and with the problems of the individual forest owner or manufacturer.

As a broad conclusion, however, with the exception of limited situations which are dealt with region by region, the Forest Service has tremendous faith in the commercial promise of timber growing to American landowners. The law of supply and demand is working steadily to create timber values which in large portions of the United States will pay fair returns on forestry as a business. The economic history of other countries which have passed through a cycle of virgin forest depletion similar to that which the United States is now traversing points to the same inevitable conclusion. The time is fast approaching when forestry, and forestry alone, will supply the enormous quantities of wood demanded by American markets. The fundamental laws of business must in the nature of things so operate as to enable the markets of forest products to be supplied at a profit to the grower of timber. The returns already being obtained from this form of land employment at many points in the eastern United States show plainly enough that this relationship between the value of timber and the cost of producing it is already coming about to a marked degree.

To the men who own forest-producing land in the United States or who are engaged in industries which require timber as raw material, forestry now offers a commercial opportunity. Satisfactory returns from forestry can not be promised in sweeping terms any more than returns from the manufacture of lumber or paper. But the opportunity for a profitable employment of capital and business talent in the growing of timber merits the same consideration and the same expert guidance as industrial opportunities in the conversion of timber. This applies with special force to the commercial institutions in the United States which have made large capital investments in manufacturing plants and distributing organizations, dependent for their maintenance upon a future supply of forest-grown material. It applies equally to the owners of land, in large tracts or farm wood lots, the earning capacity of which lies solely in the growing of trees and which, without tree growth, will become either a doubtful asset or an outright liability.



F—95445

TYPICAL OLD-GROWTH VIRGIN TIMBER IN THE DOUGLAS FIR REGION

With the large Douglas firs are a few smaller western hemlocks and western red cedars. The undergrowth of bushes is dense, and the ground is littered with the remains of fallen trees

F-95409

A YOUNG DOUGLAS FIR STAND READY FOR THE AX

Although not of large size or great age, this forest, composed almost entirely of Douglas fir, is ready for cutting. There is much active logging in such timber in many parts of the Douglas fir region

The Forest Service earnestly asks the forest landowners of the United States to determine for themselves, with the same care with which they would approach any other business problem, whether timber growing does not offer a commercial opportunity which should be grasped. It commends this series of bulletins to them, not as a complete or authoritative scheme that can forthwith be followed with profit in their own woods, but as a starting point in utilizing the opportunities that forestry may hold out.

GENERAL SITUATION IN THE DOUGLAS FIR REGION

To grow successive crops of timber on a forest property, what must be done in the woods? It is the purpose of the following pages to answer this question for the Douglas fir region. The discussion will be concerned with what must be done in the woods; it will not be concerned with what must be done in legislative halls or through corporate business reorganization to put into effect and finance the measures recommended. In considering these woods measures essential for forest renewal and forest protection, their cost and practicability will always be carefully weighed, for forestry, like any applied science, is a business.

THE FOREST AND FOREST TYPES

The Douglas fir region lies between the Pacific Ocean and the crest of the Cascade Range in western Washington and Oregon from British Columbia approximately to the California line. Except for a few meadows, prairies, and mountain barrens, the entire region was once forest clad. In the density of its forests, in the huge size of its trees, in the luxuriance of growth, this region is in the front rank. Its present timber production is large, and it promises continued large yields of virgin softwood timber for many years.

Speaking broadly, this is still a primeval forest region. Of the 28,000,000 acres of original forest, only about 4,000,000 acres have been logged. A little in addition has been slashed and burned off for agricultural use. The rest is in a state of nature. By no means, however, is every acre of natural woods bearing the quota of timber it might. It is estimated that on the advent of the white man the whole region was not bearing more than a third of the timber the land is capable of producing. The average stand for the region as a whole was probably under 30,000 feet per acre, whereas mature virgin timber ought to run 100,000 feet per acre. Many acres were denuded or bearing small young timber, and others were thinned out and patchy because of the inroads of fire.

Serious fires from time immemorial have wrought great havoc in the virgin forest, which when destroyed has usually been replaced by a "second-growth" forest of young timber. Thus there is in this region timber of various ages. There are whole townships of immature timber. The existence of so great an acreage of young forests has a very important bearing on the future stability of the lumber industry of the region.

Extensive lumbering operations are as yet almost wholly in mature timber, and it should be understood that the discussion herein of the methods of cutting and of the measures necessary for timber growing

pertains entirely to mature stands, unless otherwise specifically stated.

Of the entire lumber cut of western Oregon and Washington (excluding cedar shingles), 82 per cent is Douglas fir. Of the 371,000,000,000 feet of privately owned timber, at least 70 per cent is Douglas fir. But the timber of the entire region, though so predominantly and characteristically Douglas fir, is by no means homogeneous. Although Douglas fir occurs more or less on nearly every site, the physical differences between high and low altitudes, between coastal, valley, and mountain sites, are reflected in pronounced differences in the forest cover.

For clarity in this discussion, it is convenient to recognize the several forest types which occur in the Douglas fir region. They are the Douglas fir type proper, the fog-belt type, and the upper-slope types. Most of the timber cutting is in the Douglas fir type proper and the fog-belt type, which together include practically all the privately owned timberlands.

THE DOUGLAS FIR TYPE PROPER

A forest in which Douglas fir (*Pseudotsuga taxifolia*) comprises 60 per cent or more of the timber volume is classed as the Douglas fir type proper. This type covers at least three-quarters of the forested area of western Washington and Oregon and an even larger proportion of the area of commercial forest. Though it is spoken of as the Douglas fir type, western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*), Sitka spruce (*Picea sitchensis*), silver fir (*Abies amabilis*), noble fir (*A. nobilis*), lowland white fir (*A. grandis*), western white pine (*Pinus monticola*), and several other species of lesser consequence are mingled with the Douglas fir in greater or less degree.

Roughly speaking, the wetter the site the larger the proportion of other species in the virgin timber. The proportion of hemlock increases with altitude and with approach to the coastal fog belt. Also northward the proportion of other species than Douglas fir increases with increasing humidity and coolness.

On the other hand, in southern Oregon on the foothills of the warm dry valleys and on the hotter slopes in the mountains, Douglas fir gives place to western yellow pine (*Pinus ponderosa*).

Again, the proportion of Douglas fir diminishes as the age of the stand increases. In very old stands there is apt to be more hemlock and cedar than in young timber. The so-called second-growth stands on old burns and logged-off lands are composed to a striking degree of Douglas fir, and are therefore justly spoken of as pure Douglas fir forests.

The younger Douglas fir forests are often referred to by lumbermen as "red fir stands," while the overmature forests are called "yellow fir stands." The slash disposal and fire problem in these two subtypes is quite different in intensity.

THE FOG-BELT TYPE

The humid western slopes of the Olympic Mountains and Coast Ranges, within the so-called fog belt, carry a somewhat different type of forest from the Douglas fir type proper. Here the principal

species are Sitka spruce and western hemlock, though Douglas fir is never absent over a large area. Western red cedar and, farther south, Port Orford cedar (*Chamaecyparis lawsoniana*) are also conspicuous. Most of this type is in private ownership and is now the scene of active logging operations. The method of logging is identical with that in the Douglas fir type proper, but the brush disposal and fire protective conditions are somewhat different, and hence require a slightly different system of forest management from that suited to the Douglas fir type. Where these differences are significant the treatment for the fog belt will be mentioned separately; otherwise the two types will be considered jointly.

THE UPPER-SLOPE TYPES

On the upper slopes of the Cascade, Olympic, and Siskiyou Mountains the forest cover is largely of species other than Douglas fir, which at certain altitudes disappears altogether. It is needless to go into a description of these mountain types, which are made up of a varying proportion of silver fir, noble fir, mountain hemlock (*Tsuga mertensiana*), western hemlock, western white pine, Alaska cedar (*Chamaecyparis nootkatensis*), lodgepole pine (*Pinus contorta*), Douglas fir, alpine fir (*Abies lasiocarpa*), etc. Some of these upper-slope forests have high commercial value, but for the most part they are so inaccessible that they will not be logged until the virgin stands at lower altitudes have been exploited. As they will not for some time to come play an important rôle in the timber-growing problem of the Douglas fir region, and as they lie mostly within the national forests, these upper-slope types are not considered in the following pages.

FACTORS AFFECTING NATURAL REFORESTATION IN THE DOUGLAS FIR TYPE

As Douglas fir is so superior a tree and is the one upon which the lumber industry of the region is built, it is natural that landowners and foresters should desire to obtain chiefly Douglas fir in the new crop wherever it will grow satisfactorily. The forests of the future should be composed to a large degree of this species, and in the Douglas fir type proper forest management will be directed toward this end. Other species, such as hemlock, cedar, and silver fir, will come in to some extent; it would not be easy to prevent them, even if it were desirable to do so. Where the production of pulp wood is the object of the owner, as it will be increasingly in the spruce-hemlock forests of the fog belt, it may be advisable to manage the land with a view to extending spruce in the new crop. Where the land is managed to obtain principally Douglas fir in the new crop, consideration of the secondary species is of no consequence. As a matter of fact, the treatment that results in regeneration of Douglas fir is also sufficiently favorable for that tree's natural associates.

It may be said at the outset that Douglas fir has every characteristic favorable for its abundant reproduction in this region and no inherent traits to prevent its plentiful natural propagation. An abundant and frequent seeder, its seed germinates quickly and vigorously in almost any kind of seed bed, and the seedlings grow hardily and have good resistance.

It is a matter of common observation that many excellent stands of seedlings or saplings occur on lands logged off recently and on those cut over some time ago; and were all cut-over lands in this condition there would be no "reforestation problem" and no occasion for this discussion. However, on many other areas of equally favorable physical environment little or no reproduction is to be found. Wherever this occurs, adverse factors are present. To understand what present-day practices are favorable and what are unfavorable to the successful establishment of a new crop of timber, certain facts about Douglas fir and about its reproduction and protection must be known. These are discussed in the following pages, in so far as they bear on the measures necessary to insure a new crop after logging.

SEED PRODUCTION

Seed is produced in abundance from the time the stands are about 25 years old until they are decrepit. Bountiful seed crops are not annual, but occur perhaps two or three times per decade; about every third year practically no seed is borne. There is considerable uniformity the region over in the heaviness of the seed crop.

SEED DISSEMINATION

Douglas fir seed (as well as that of its principal associates, cedar and hemlock) ripens in late August, the cones open, and much of the seed is released then. With damp weather the cones partially close, and when they open again on dry days more seed is released. In this way the dispersion of the seed is continued through the fall and early winter. An appreciable amount of good seed can be found in the cones in midwinter.

The light-winged Douglas fir seed is borne away from the parent tree by the wind and is subject to the wind's vagaries. The seed dispersed on still days naturally alights close by; in high winds it may fly far. The maximum distance at which seed trees can do effective seeding is not known; it depends, among other things, upon topography, the season, and the amount of seed dispersed. Crusted snow could easily increase the distance that winter-sown seed may be carried by wind. Birds and animals undoubtedly have a rôle in disseminating some seed. The more abundant the source of seed, the greater the effective seeding distance. A single seed tree naturally will not seed effectively for as great a distance as a solid bank of timber. Beyond a quarter mile on level ground even a large mass of trees will probably not do effective seeding, and even up to that distance they may take several years to seed the ground thoroughly.

Much freshly logged and burned land is seeded up by adjacent uncut timber, which is often close enough to be effective until cut in the advancing logging operation.

SEED STORAGE IN THE DUFF

An acre of virgin forest during a favorable seed year bears hundreds of thousands of seeds. These fall to the ground, and many are eaten by birds, insects, and animals; some decay. Others alight on favorable spots and germinate the following spring, but those seedlings which start in the shade of the virgin forest are almost sure to

succumb the first season. Some seed fails to germinate and yet falls on ground favorable for its preservation—perhaps it is covered lightly by the leaf fall or by animal activity, and so is "stored" in the cool duff. The disturbance of the ground by logging naturally buries some seed in mineral soil. A small percentage of this stored seed probably remains viable past the first season, and that which escapes injury when the virgin forest is cut and the slash burned germinates the succeeding spring in response to the warmth of the sunlight on the burned, logged-off land. Where there are crown fires in virgin timber, this stored seed seems to be a very potent factor in insuring prompt reforestation.[1] On logged and not too severely burned lands some reproduction undoubtedly comes from stored seed, at least when a good seed crop has been borne the preceding autumn. The rest of the reproduction—if any—comes from seed blown from near-by seed trees and standing timber. The proportion from each source depends upon local circumstances, and the evidence now at hand does not warrant any generalized statements that would apply to all localities and conditions.

SLASH BURNING

The theory has sometimes been advanced that broadcast slash burning is a necessary measure in securing reforestation, in that it bares the ground and stimulates germination; but detailed study strongly points to the conclusion that reproduction of Douglas fir starts more promptly and more abundantly where the slash is not burned. A comparison of a considerable number of burned areas with similar but unburned logged-off land, in each case quite recently cut over, shows 10 or more seedlings on the unburned to every seedling on the burned ground. Slash burning, however, because it lessens the water content of the surface soil, probably increases the proportion of Douglas fir over hemlock in the new crop.

The chief reason for slash burning as a forestry measure is to reduce the fire menace of the vast amount of dry litter, that there may be less chance of accidental fires later. For most of the Douglas fir region broadcast slash burning has been accepted by lumbermen and foresters as an essential practice, a "necessary evil." Until there is a greater degree of fire prevention, slash burning is a wise precaution against a greater evil—uncontrollable summer fires.

Nevertheless a slash fire, no matter how intensely it burns, never leaves an area immune to subsequent fires. In this region even the most thoroughgoing burning fails to consume all the inflammable trash that is on the ground; many of the coarser limbs, tops, cull logs, and rotten windfalls are left; some of the duff is only charred on top; the standing snags are not burned down; and the unmerchantable green trees that are left may be killed but are not consumed. Areas burned by a good slash fire have been known to reburn the same year, though ordinarily the second fire would not cover all of the surface. All too commonly a part reburns when the fresh slash on the adjoining area is burned.

[1] HOFMANN, J. V. THE NATURAL REGENERATION OF DOUGLAS FIR IN THE PACIFIC NORTHWEST. U. S. Dept. Agr. Bul. 1200, 63 p., illus. 1924.

Following the first slash fire, various weeds—mostly those not found in the virgin forest—take possession of the ground and create a vegetative cover which, dying and drying up each year, adds greatly to the inflammability and to the danger of subsequent fires. Chief among these weeds are fireweed, hawkweed, pearly everlasting, bracken fern, and thistle. After five years or so, if the area is not reburned, these plants give place to bushes such as hazel, alder, salmonberry, vine maple, and elderberry, and to tree saplings; and with the decrease in the annual plants and the increase in the shade-producing and less combustible brush, inflammability declines.

In certain portions of the Douglas fir region there is considerable small stuff in the virgin forest—understory hemlocks 6 to 16 inches in diameter, small cedars, and patches of unmerchantable pole wood. Some trees that are too small to be utilized remain standing after logging is completed; but trees of this nature, especially hemlocks and cedars, are very apt to be killed by the slash fire. They are killed, but not consumed. After a few years' exposure to the elements and decay they fall over, or their limbs break off, and the ground becomes littered with dry trash which is an invitation to fire. Where there is much of this small unmerchantable stuff left, the inflammability of the area is about as great after the slash fire as before. There is a good deal of this class of logged-off land in the fog-belt type, where small hemlocks abound.

These facts indicate that slash burning, as now practiced, is at best a halfway measure and that it leaves the ground in such condition that there is grave likelihood of recurrent fires.

IMPORTANCE OF PROMPT SLASH DISPOSAL

Fresh seed that becomes mixed with mineral soil or lies in a protected spot may escape destruction by the slash fire, but tender seedlings can not. This is something to remember. If logged-off land carries a supply of seed—either that shed by the forest before cutting and stored in the duff or that blown in from near-by standing timber after logging—it is better to burn the slash before that seed has germinated than to delay the burning until after the seed sprouts. If the slash burning lags a year, or even a summer season, after logging, the majority of the seed supply then on the ground will have germinated, and the tender sprouts are almost sure to be wiped out by the fire. In such an event the only chances for the area to reforest naturally come from such seed trees as may be left, from an occasional ungerminated seed that still lies dormant in the duff, or from seed blown in from a neighboring bank of green timber. Be it remembered, moreover, that in the normal progress of a logging job the standing timber retreats farther and farther from the older cut-over land; it is the first season after logging that land has the best chance of being reseeded from the virgin stand. If the full benefit of seed from the neighboring uncut timber is to be obtained the slash burning ought to be done before this seed is dispersed.

In short, delayed slash burning on logged-off lands is incompatible with successful natural reforestation. This is also true of second fires. Even when the fire does not run over the ground completely but burns skippingly, it injures the oncoming crop of timber seriously by making a patchy distribution of the trees, causing understocking, and fire-scarring seedlings which survive. Any fire which runs over

reproducing logged-off lands, therefore, whether it be an all-killing fire or not, should be regarded as damaging to the welfare of the forest.

The season of the year at which slash burning should be done is of considerable moment, not only because of the effect upon reproduction but because of the relative difficulty of handling fire in the spring and in the fall.

Spring slash fires consume less of the deeper layer of duff and humus than do fall fires. Consequently more of the seed of the last and earlier seed crops might be expected to survive spring fires than fall fires. On the other hand spring burning has some practical disadvantages. Spring fires leave unburned more material to invite a later fire than do fall fires. Spring burning, also, is risky unless the operator is willing and prepared to put out every smoldering fire before the dry season, in case late spring rains do not do so.

There are difficulties and disadvantages in burning at any season, and the operator must compare all the advantages and all the disadvantages from every angle for each particular set of conditions. It is obvious that slash burning, both in the spring and fall, gives a semiannual clean-up which is better from the fire-protection standpoint than doing all the burning only once a year. This, together with the very positive advantages to reforestation of prompt burning, point to the wisdom of a "burn as you go" policy; i. e., burning small areas of fresh slash as fast as they accumulate, using both the spring and the fall and even the winter season, as circumstances may allow.

THE PLACE OF SINGLE SEED TREES IN DOUGLAS FIR REFORESTATION

It has been shown above that the splendid reproduction which characterizes much logged-off land in the Douglas fir region comes chiefly either from seed cast by the virgin forest before logging or that blown in from adjoining blocks of uncut timber. Where a large area is logged absolutely clean, there is no other source of seed.

In some logging operations it is the practice to leave here and there single trees which are too defective to be worth logging. This was formerly much more common than it is now. On the national forests it is the standard practice to leave an average of about two seed trees to the acre, usually misshapen or conky trees.

In some parts of the Douglas fir region it is not uncommon to find an average of two or three big conky trees per acre of which the merchantable value is little or nothing, yet which have a potential value as seed trees if left intact. The effect of such trees in assuring adequate seeding up of their environs is very important. There are other parts of the Douglas fir region where the timber is so sound that no seed tree can be left without a sacrifice of commercial stumpage.

Any trees of seed-producing character that can survive contribute toward the reforestation of the land and are particularly useful if an accidental fire wipes out the initial crop of seedlings. The smaller trees of a stand, which might by chance be left, do not function very well as seed trees because they are quite likely to be knocked down by the falling of their larger neighbors, to be killed by the slash fire, or to fail to produce seed. Even some of the larger trees may be killed by the slash fire, principally from heat damage to foliage rather than to the living tissues of the trunk.

The ability of single Douglas fir trees to withstand wind is somewhat variable; soil and situation affect this characteristic materially. It may be expected that some of the single trees, of whatever size, left on logging operations will be blown down, but experience has shown that the greatest loss is in the first few years after cutting and that on most soils the loss is not serious.

The wisdom of leaving conky trees for seed has been questioned. This need not be gone into here more than to say that the prevalent fungus which causes conk rot (*Trametes pini*) is a disease of the heartwood, and therefore does not affect the vitality of the tree; that the disease is not transmitted through the seed; that it is a disease of old trees and therefore not to be greatly feared in the new crop which will be harvested probably before it comes to the age of bad infection. Foresters and pathologists are agreed that the leaving of such trees does not practically increase the danger of infection in the new crop and that the cutting of these few conky trees merely to rid the area of infection would be a trifling measure, so universal is the disease.

REFORESTATION FACTORS IN THE FOG BELT

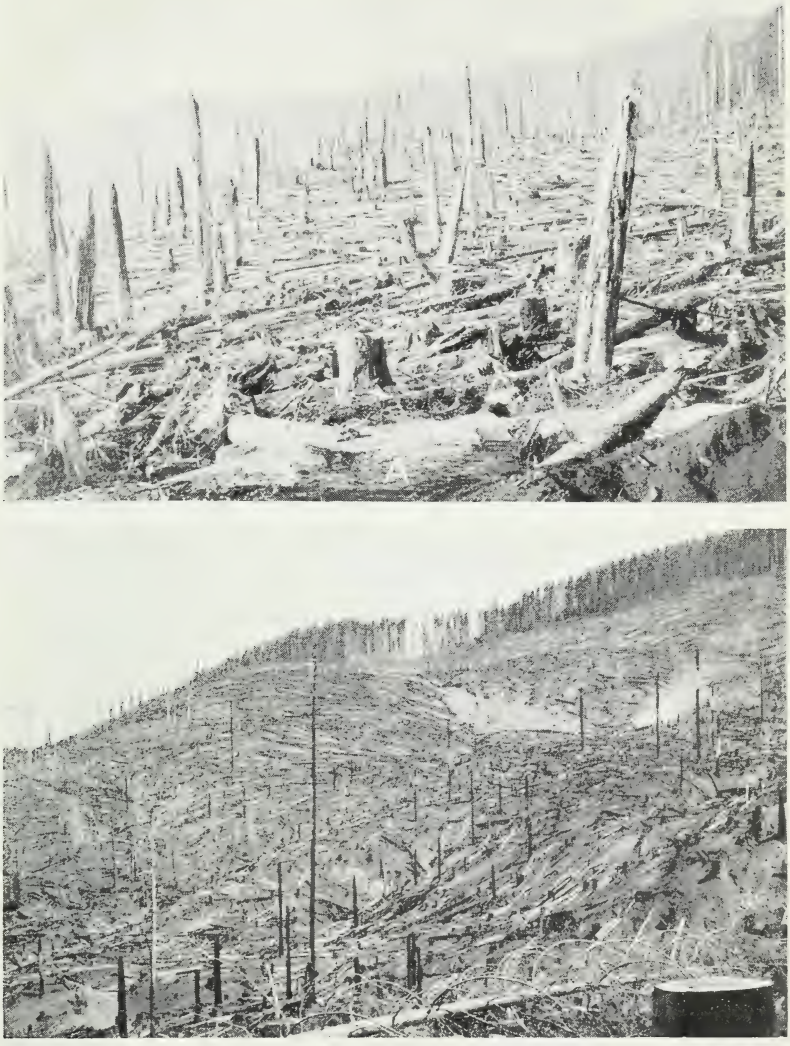
The above discussion of the factors affecting reforestation in the Douglas fir type proper applies broadly to the fog-belt type, with a few noteworthy points of difference. Spruce and hemlock, which either with or without Douglas fir are the species common in the fog-belt forests, both reproduce vigorously on logged-off land in very much the same way as does Douglas fir. Hemlock is enormously prolific on moist or shaded sites. Both species are more exacting as to moisture requirements than fir, and hence germination is best in duff and where the site is not too dry. Also, as has already been seen, slash burning, which exposes a site to drying out, is likely to be more favorable to Douglas fir than to hemlock and spruce.

Both spruce and hemlock are less windfirm than Douglas fir; therefore, patches of pole wood or scattered seed trees of these species left from logging are less likely than Douglas fir to survive.

The fire problem is less difficult in the fog-belt than in the Douglas fir type, for accidental burning of slashings is easier to guard against. It is even difficult to burn slashings intentionally in certain fall and spring seasons because of the soaking ocean fogs. Nevertheless in some years the fog belt has dry spells equal to any in the Cascade region, and at such times the fire risk becomes exceedingly acute. Some of the most disastrous conflagrations in the Northwest have been in the fog belt.

Hemlock and spruce slash is less combustible than Douglas fir brush; the needles fall off the first season, and the fog-belt climate promotes a luxuriant growth of shrubbery which quickly clothes logged-off land. Where slash fires do not follow logging, this shrubbery consists of rather noninflammable growth, such as salmonberry, alder, elderberry, red huckleberry, and Christmas fern, and within four or five years makes an almost continuous cover which keeps green all summer. On such areas the fire risk quickly diminishes to that of the virgin forest. This cover does not seem to deter forest reproduction.

Where logged-off land in this type is burned over, the less inflammable shrubbery is killed back and in its place come the more inflam-



F—196078—163285

CHARACTERISTIC LOGGED-OFF LAND IN THE DOUGLAS FIR REGION

About 200,000 acres of such land as this is logged off each year. In the upper picture the slash has not yet been fired eight months after a ruthless clear-cutting, and the unfelled snags make control of fire here especially difficult. In the lower view a spring burn has followed clear-cutting. The timber on the ridge may seed a strip of ground near by if it is not cut immediately, but the reforestation of the rest is dubious unless seed stored in the ground survived the slash fire

F-100017

THE RESULT OF PROPER LOGGING AND PROTECTION

Two thousand Douglas fir saplings per acre, of Christmas-tree size, on land that has been well protected since logging and immediate slash burning 10 years ago

mable weeds—hawkweed, thistle, bracken fern, and fireweed. These prolong the period of acute fire risk until the less inflammable bushes have regained the ground or the young trees have made a continuous cover.

LOGGING AS IT AFFECTS REFORESTATION

In western Washington there is cut over annually some 145,000 acres of mature timber, and in western Oregon about 60,000 acres. This cut is in both the Douglas fir type proper and the fog belt, most of it in the former. Practically all of it—98 per cent—is on private land. The following discussion applies to the methods used on the private lands without reference to the system of cutting in effect on the national forests under governmental regulation. Briefly, present logging practice is about as follows:

The entire stand is felled, except such scattered trees as are too defective from decay or other causes to be of value to the logger and such small trees as are unmerchantable. The logs are then removed by powerful donkey engines or by skidders, either by the overhead (or skyline) system, by the high-lead method or, rarely now, by the ground-yarding method. Railroads are customarily used in conjunction with the larger operations. Most operations are continuous the year through or are suspended only for a short period in the winter or when the market is off.

The quantity of débris—cull logs, tops, fallen rotten trees, branches, and broken-down undergrowth—which litters the ground on the conclusion of logging is enormous. Ordinarily this slashing is burned broadcast at a convenient and safe time from a few months to two or three years after logging, unless, as is very often the case, it has already caught fire accidentally. Of course, the fire hazard in a logging operation does not all come from the operation itself. Some of the fires are due to other agencies, including lightning, berry pickers, hunters, fishermen, and campers, and common-carrier railroads.

Disposal of slashings which are a menace is required by the laws of both States. Slash burning is done either in the spring or fall but more commonly in the fall. There is little preparation for the slash burn except removal of logging equipment from the zone of danger. An effort is made to keep the fire out of standing timber and the operation. Too often the burning is taken casually and no forehanded aggressive plans are made in advance to control the fire effectively. Sometimes the slash fire spreads to lands once burned, and unless there is timber, equipment, or other property in its path, but slight effort if any is usually made to prevent it from doing so.

Upon the conclusion of "falling," logging, and slash disposal, the average area is usually devoid of living trees. The smaller trees left by the fallers have for the most part been knocked down by the logging lines or burned in the slash fire, and of the few larger trees which were culled and left standing some if not all have been killed in the broadcast burning. Standing dead trees or "snags," varying in height from a few feet to 200 feet, are scattered over the area. Their abundance depends upon the number of dead trees in the original forest and the type of logging used. A check of the snags on a number of representative logged-off tracts shows anywhere from 1 snag to each 5 acres to 5 snags to the acre, considering only those over 20 inches in diameter. On a few operations snags are

felled during logging to reduce the fire danger, to avoid accidents to employees, and to facilitate handling the yarding lines. Some of the larger snags are cut for fuel on most operations. The law requires that all snags about donkey settings be felled.

Every up-to-date operator makes some effort at protection against fire, but there are few in this region whose precautions and protective organization are really adequate to cope with the risks. Such activities are subordinated to the major business of getting out logs. A point to be emphasized here is that at the present time every logging company's protective system is intended primarily for the safeguarding of virgin timber, camps, felled logs, and equipment, and not for protecting reproduction on cut-over land. Logged-off land is protected and fires are fought thereon chiefly to keep fire from spreading to commercial timber or improvements, or to comply with the State law.

In short, up to the present time the system of logging private lands in the Douglas fir region, with but few exceptions, provides no intentional measures to insure the reforestation of these lands. Whatever reproduction takes place does so, for the most part, in spite of present methods, not as a result of them. This is not stated as a criticism of the Douglas fir lumberman; it is a plain statement of fact and gives occasion for the recommendations to be made later.

STATUS OF REFORESTATION UNDER PRESENT PRACTICES

There is in the Douglas fir region so great an acreage of well-reforesting cut-over land that it may very properly be asked whether methods of logging used in the past have not been satisfactorily conducive to new growth, and why therefore any change in present practices should be recommended.

Competent authorities differ widely as to the proportion of logged-off land in private ownership which is reforesting. In the absence of reliable field data for the entire region it has been estimated in the course of this study that 60 per cent is reforesting and 40 per cent is barren of useful tree growth. Even if 60 per cent is growing a new crop, that is far from satisfactory, especially when it is borne in mind that much land so classified is not bearing a fully stocked or uniformly well-stocked stand of new growth and therefore can not be counted upon to yield the returns that the land should produce. Furthermore, most of that which is restocked is so subject to fire, because of inadequate protection, that some of it is sure to be added later to the denuded class.

There is another factor to remember. The system of logging used 20 to 40 years ago gave better reproduction than follows present-day methods. Hence a smaller proportion of the land being cut over to-day is reforesting than in the past. Under the "bull-team" method the fire risk was less than it is under the present donkey-engine and railroad method. Freshly cut-over land then had a better chance to escape being accidentally burned and reburned. The present-day precautions against fire and the vigilance of protective organizations hardly compensate for the increased size and abundance of logging operations, their proximity to one another, with the attendant risk from men and engines—not to mention the increasing risk on cut-over areas from the general public and settlers.

In the early days cutting was not so close as it is at present; many good-sized trees were left standing and naturally helped seed up the surrounding country. The heavy high-speed equipment used nowadays tears down the patches of small timber and potential seed trees that would have survived the bull-team method or ground logging with small donkeys.

A further factor militating against natural reforestation is the character of the country to which the logging industry has now spread. The land now being operated is steeper, rougher, and rockier than the valley and foothill country where the industry centered two decades ago. It is a matter of common observation that the rougher the country the more disastrous are fires and the more does the logging tear up the ground and smash reserved trees. Also, the poor soil that goes with mountainous topography gives correspondingly poorer nurture to reproduction than do the deep soils of the foothills, and erosion on mountain slopes is a further handicap to tree seedlings. The land logged more than two decades ago was mostly agricultural land; that now being logged is mostly land unsuited to farming.

There is no doubt that the tendency of modern logging is to make conditions less favorable for timber growing than did the logging of the early days. The urgency for taking positive, conscious measures to assure reforestation after logging is double what it was 25 years ago.

MINIMUM MEASURES TO KEEP FOREST LAND PRODUCTIVE

FIRE CONTROL THE PARAMOUNT CONSIDERATION

Enough has been said above to show that Douglas fir and its associates would be quite able to perpetuate themselves after a fashion, even in spite of most destructive methods of logging, were it not for uncontrolled fires. The growing of continuous crops of timber in the Douglas fir region, therefore, is primarily contingent upon the control of fire. This is the paramount consideration. For this reason the following pages are devoted very largely to a discussion of the problem of protection against fire.

The specific measures set forth below are the practical essentials of a forest-perpetuation program. Whether they should be put into effect by voluntary agreement, subsidy, law, or any other means need not be discussed here, nor is any distinction made here between the measures already enforceable under existing law and those which are not. Here are considered merely the principles of woods management necessary to grow successive crops of timber. The subject very conveniently falls under four main topics, which will be used as a basis for the discussion in this bulletin:

Care of the virgin forest.
Treatment of the forest and cut-over land during logging.
Treatment of the new forest crop after logging.
Regional cooperative system of forest protection.

It should be borne in mind, however, that these four topics fall under two broad classes of protective effort:

(1) The prevention and suppression of fire in connection with logging operations. Logging creates an extraordinary hazard adjacent to the operation on the lands of the operator especially, and the fire problem there is one for the operator to handle himself. It is quite apart from the general fire problem common to all forest land of the region.

(2) Protection of forests against fire in the region at large. Because of interlacing ownership and the public's large share in causing fires, the protection of the forests of the region becomes in part a matter for public action and requires a widespread cooperative organization.

CARE OF THE VIRGIN FOREST

The principal provision necessary in the virgin woods of the Douglas fir region is the prevention of fires. Fires may be either surface or crown fires. Surface fires do relatively little damage in the virgin forest other than killing a tree here and there, pitching the butts, inviting butt rots, encouraging the growth of brush, making tinder for subsequent fires, and depleting the soil's fertility. They are, however, always liable to develop into crown fires which kill all in their path and may wipe out in a few hours the entire commercial value of a forest property except for such salvage value as dead timber may have. Therefore *the absolute prevention of fire in virgin woods* is the desired goal for successful forest management. This should be the objective even though its perfect attainment may be beyond reach at once. The smaller the acreage burned over each year by any class of fire the better the forestry.

Upon the owners' initiative and under the compulsion of the State laws, most of the virgin commercial forest of the region is now given fairly effective protection. Better protection still is necessary, but not so much in the virgin timber itself as in the logged-off land and slashings, where most of the fires start that threaten virgin timber. A discussion of protection methods and organization is given later under the heading "Regional cooperative system of forest protection."

Aside from protection against fire, the measures necessary for proper care of virgin forests prior to cutting are of minor importance. There are, of course, the prevention of trespass and the salvage of fire-killed or other dead timber. There may be occasional outbreaks of insect or fungous enemies which require the services of competent specialists to determine the nature of the trouble and to prescribe possible remedies. Catastrophies due to the elements, such as the Olympic blow down of 1920, create special problems of salvage and protection which must be settled as they arise.

TREATMENT OF THE FOREST AND CUT-OVER LAND DURING LOGGING

For getting a new crop of timber started in the Douglas fir region the all-important principle is to give nature a chance. No radical modification of present logging methods is necessary, but to attain satisfactory reforestation slash disposal and fire control must be made much more effective than they are to-day, and better provision must be made for insuring sufficient seed. The technic of

these processes may be bettered in the ways outlined below. Expressed in their simplest form, the requirements essential, during logging, to keeping forest land productive are:

(1) Direct protection. Have an effective protective organization with proper equipment, personnel, etc., so that there may be no accidental fires in the operation or on the cut-over lands.

(2) "Fireproofing" cut-over lands. Reduce the inflammability of cut-over areas to a minimum by close utilization, by falling snags, by making sure of thorough slash burns, and by keeping slash fires out of pole wood which they might kill.

(3) Prompt and careful slash burning. If the slash must be burned as a precaution against fire, burn it as soon after the felling of the timber as practicable, and give to this operation foresight, intelligence, and care.

(4) Seed supply. Leave standing for seed occasional living trees which do not have a saw-log value sufficient to justify their logging or which may be left without undue expense or inconvenience to the operator. Otherwise, so plan the operation that each block of freshly cut-over land, after it has been slash burned, may have a chance to receive wind-blown seed from adjoining standing timber.

To carry out these measures, certain phases of the average logging camp's administration must be modified or strengthened. Of the requirements listed below every one is now in effect in one camp or another, but probably no operation practices all of them simultaneously. Some of the most successful operators, however, come very near to complying with all. The measures are all considered essential throughout the Douglas fir region except as their application is specifically qualified.

DIRECT PROTECTION

An effective organization and equipment for direct protection of cut-over land and land being cut over is perhaps the most important requisite to forest perpetuation in this region. Below are listed, without any attempt to elaborate them, the principal features of an ideal yet practicable protective system. This direct protection, naturally to be financed by the operator, should cover not only the areas of felled timber and unburned slash, but also logged land which is exposed to fire by the operation.

It must be remembered, however, that the physical details of the organization are less important than the spirit which actuates it. The perfunctory carrying out of a set of laws and rules will accomplish little. First and foremost the organization for protection against fire must be imbued by an enthusiasm and zeal absolutely to prevent and suppress fires. Everyone in the organization must be made to realize that fires about a logging operation are dangerous and that it does not pay to take chances with them; that even when conditions seem safe an untended fire or a small fire in a dangerous place may, with a change in the weather, develop at short notice into a conflagration. The fire system should be inspected by the superintendent, manager, and owners as vigorously as any other phase of the enterprise.

The following requirements are naturally limited to the "fire season," but no attempt is made to define the season, for it varies

greatly throughout the region and from year to year. Some of these should be in effect even longer than the "closed season" defined by law. No attempt is made to coordinate these requirements with existing law.[2]

(1) In every logging operation employing over 30 men in the woods, there should be a camp firewarden, paid by the company and commissioned by the State as deputy firewarden, whose sole duties during the fire season are the prevention and suppression of fires on the operation. He should be given authority and be held accountable, be a man of intelligence and energy, and know how to get results in handling fire and men. In smaller camps, the camp foreman can perform the duties of camp firewarden or assign some one else to this work.

(2) Every logging camp should be organized for fire prevention and suppression. There should be a fire signal, and the men should be instructed as to their duties in case of fire. Employees should be instructed in the requirements of the State law. Logging plans should be made with the thought of fire control. Companies should make rules about smoking, care of spark arresters, dumping hot ashes, sanding flues, blasting, and building camp fires or rubbish fires, and have the camp firewarden enforce them.

(3) The camp firewarden should have firemen working directly under him who devote their time exclusively to fire prevention. They should patrol the railroad tracks (each carrying a shovel or other fire-fighting tool), watch donkeys at noon and night, and attend to smoldering fires. Their number would depend upon conditions, but it is thought that one man for each 30,000 feet cut daily during the fire season is a minimum. The camp firewarden can perform the duties of a fireman (patrolman) in small camps. Firemen should be able-bodied, handy, and trustworthy.

(4) Every operator should keep in touch with the "fire weather" warning service of the Weather Bureau or make his own observations of relative humidity and other climatic factors. In time of acute fire risk he should increase his precautionary measures, and make doubly sure that every right-of-way fire, camp bonfire, and "hold over" from slash burning is out. If especially dangerous conditions are predicted, the operaton should be suspended for a day or two until the dry "east wind" spell has passed.

(5) All wood or coal-burning steam engines, locomotive and stationary, should be equipped with spark arresters which are effective and which are kept in repair. Oil-burning locomotives or other oil burners with inside exhaust should have at least a screen bonnet over the stack. All new wood- or coal-burning donkey engines purchased should be equipped so that they may exhaust outside the stack. Oil burners should not be moved while a wood fire is on the grate. Ash pans should be kept in repair so that they will not leak coals. Flues of oil burners should be sanded frequently, but only in safe areas.

(6) Fire-fighting equipment should be ready for use at strategic places, preferably in tool boxes, marked "For Fire Only." For example, each locomotive and each donkey (or group of donkeys,

[2] A more detailed discussion of this subject may be found in the following: Osborne, W. B., Jr. Fire fighting. *In* The Western Fire Fighter's Manual, chap. 7, 66 p., illus. 1919. It is full of practical, helpful suggestions.

whether steam or electric) should have a small force pump, sufficient hose, open barrels of water, buckets, hand pumps, mattocks, shovels, and axes.

(7) Steam-donkey settings to be occupied during the summer should be cleared of inflammable material in advance. The ground about each donkey engine in use should be wet down in dry weather, morning, noon, and evening, for a radius of 75 feet. This presupposes either a gravity-pressure water system to the donkey or a pump and adequate water storage. When there is a pressure system, set sprinklers are effective.

(8) The operation should be so equipped that water in quantity may be quickly available under pressure on every part of the cut-over area to which the logging lines will be laid during the four or five dangerous months, and on which the slash has not been burned. This is to make possible the suppression of incipient fires with water and the putting out of lingering smokes after slash burning. This is an important provision where either electric or steam donkeys are used. Water under pressure may be obtained, according to circumstances, in any one of several ways, all of which presuppose plenty of serviceable hose:

A gravity system through pipes, ordinarily along the railroad track, with frequent taps and pressure sufficient to reach any part of the area quickly with hose.

A pumping system sufficient to deliver water as above.

A large tank car stationed at a strategic point and kept full of water, and sufficient hose to reach any part of the area, under the presumption that there are locomotive facilities to move this car as needed, proper trackage arrangements, and chances for quick refilling.

A gasoline tank car equipped with pump and hose and carrying considerable water.

A portable rotary pump, with hose (carried on speeder or auto or by hand), where there is abundant water at points to which the pump may be taken and from which all parts of the area are within reasonable hose reach.

Any combination of these five general systems might be used. It should be understood that there may be exceptional operations where, because of topography or water supply, the above requirement can not be carried out to the letter.

FIREPROOFING CUT-OVER LAND, OR INDIRECT PROTECTION

The average cut-over area in the heart of an active operation is so great a fire menace that, even after slash burning, repeated fires are not unusual. Hence the problem that confronts those who are interested in natural reforestation is to make these areas as safe as possible against fires. This might be called fireproofing cut-over land, though this is an exaggerated term, for it is of course impossible to make this land entirely proof against fire.

There are some grounds for argument as to the relative wisdom of spending money for fireproofing measures (like snag "falling") and of spending money for direct protection. Neither method can be expected to give absolute security against property losses and fire-fighting bills, but up to a certain point it is definitely worth while to

spend money to make the physical conditions unfavorable to fire. There are several ways of helping to immunize against fires, or at least to make fires easier to control.

(1) First and foremost is burning the slash after logging is completed, to rid the ground of the worst of the inflammable débris. This is so important a topic that it is treated separately in the section following.

(2) Naturally the closer the utilization the less serious will be the fire menace, for the more material removed from the ground the less there is left to carry fire. It might be supposed that competitive pressure would regulate utilization uniformly, but the great variation in the closeness of use of the timber on contiguous operations disproves that. Cull material should be used for fuel. Markets that will absorb the lower-grade logs should be catered to, that as much of the tree as possible may be taken out of the woods. Better markets for pulp wood, fuel, and chemical by-products will make practicable a better clean-up of the logged-off land in some sections. Well cleaned-up ground is an asset to any owner who wishes to grow successive crops of timber.

(3) Snags (standing dead trees) are great hindrances to fire control, for they catch fire easily and act as flaming torches, scattering fire far and wide. It is highly desirable to get them all down. It should be a minimum requirement that prior to the first slash-burning season following logging all snags over 15 feet high and within 150 feet of railroad tracks or of donkey-engine settings should be felled, as well as all snags over 15 feet high and 20 inches in diameter anywhere on the area. It is still better to "fall" the snags simultaneously with the green timber, and many loggers prefer to do so. Some snags have a value for donkey wood; some have a log value that helps offset the cost of "falling." Also, their removal facilitates logging, lessens the number of accidents, and lowers the fire hazard and the fire-fighting bills of the operation. Hence the cost of snag "falling" is by no means all a proper charge against reforestation.

Sometimes, as in old burns, the number of snags is so large that to cut them would be too costly. Here some modification of this requirement must be made, such as "falling" only the snags about the edges of each season's logging area.

(4) The débris resulting from clearing rights of way should be burned before the dry season in order to prevent the formation of fire traps along these routes of travel and to gridiron the tract with a series of fire lines the width of the cutting. At the same time, as an added precaution, the ground should be cleared of rotten wood and dry undergrowth for a few feet beyond the edges of the rights of way. That will lessen locomotive-spark and cigarette fires. A thorough clearing around camps in advance of location of buildings will prevent house fires, rubbish fires, or burning tobacco from igniting the slashings.

PROMPT AND CAREFUL SLASH BURNING IN THE DOUGLAS FIR TYPE

The following major premises are generally accepted for slash burning in the Douglas fir type proper:

(1) Slash burning is a precaution against accidental fires.

(2) Any other method than broadcast burning is out of the question, because of the enormous expense of piling the volume of débris found in these slashings.

(3) From the point of view of promoting reproduction, the promptness with which the slashing is burned is most important.

(4) Areas once burned should not be reburned.

(5) A "burn as you go" policy—i. e., firing small areas both spring and fall—is wise from both the reproduction and the protection standpoints.

Broadcast burning of slashings following clean cutting is the desirable practice throughout the Douglas fir type proper. Exception to this general principle should be made where there is so much small standing timber sure to be killed by the slash fire that the inflammability would not be abated by burning, or where there is very little débris, as on the upper part of a slope with downhill logging. There is, of course, no use in burning unless the objective of lowering inflammability for the area is attained.

Slash burning is now required by law in both Oregon and Washington, but on the majority of operations it has been conducted without thought for its effect upon reforestation and therefore with unsatisfactory, even disastrous, results. It is clear that this important work must be better done if there is to be a satisfactory crop of new timber in the region, and also if fire-fighting bills are to be kept within reason. The following practice should be generally observed.

PREPARATION FOR BURNING

Slash disposal should be considered an essential part of the season's operations, as much as railroad building or rigging spar trees. It must be prepared for well in advance. Prior to the slash-burning time, blocks of logged-off land should be definitely designated for burning and should be got in shape for burning—snags felled, equipment moved out, and preparations made for controlling the fire. Thus, when the right weather comes there will be no excuse for not burning.

In view of the imperative necessity of prompt burning, it should be the rule to prepare for burning each spring and each fall. Occasionally, however, the weather is unfavorable for successful burning, turning suddenly too wet or too dry and staying so for an entire spring or fall. Except in these unfavorable seasons, each block of slash can be burned within six months after "falling." Local conditions may give a decided advantage to one season of the year over another, and the wise operator will vary his practice accordingly. At low altitudes early spring burning may be feasible when at high altitudes it is impossible. It may not be practical to burn north slopes on the same day as south slopes. The spring burning season should not be allowed to extend into early summer, for late burning (in June, for example) has often a disastrous aftermath.

EXECUTION OF BURNING

Too much emphasis can not be placed upon the necessity for intelligent, careful execution of the burning. The superintendent or camp firewarden should be responsible for this work, and he should be given ample assistance in setting the fire and holding it until safe.

Fire lines will sometimes be necessary. At the time when it is proper to burn slash, fire will not run much in green timber. There is greater danger of the fire spreading to cut-over land once burned or to areas from which the logs have not yet been hauled out, and here some fire-line building may be a wise and necessary precaution.

It is not within the scope of this bulletin to treat comprehensively of the complicated art of brush burning, but a few points may illustrate what should constitute the proper carrying out of a brush-burning job.

(1) The area selected for burning should be laid off with reference to topography, cover, and natural firebreaks, so that the fire may be held to that area, and so that when adjoining land is logged and burned the next season the fire may not trespass on the area already burned.

(2) The dryness of the slash and surrounding country should be studied, so that both may be right before a fire is started. Burning slash that is too wet to burn clean is as undesirable as burning slash that is dangerously dry.

(3) A forecast of the weather should be made and the relative humidity of the atmosphere noted. The United States Weather Bureau may be consulted by phone if desirable, so that the fire will not be set on the eve of a hot, dry, or windy spell.

(4) The time of day or night for the burn should be chosen with regard to humidity, local air currents, etc., it being borne in mind that a thorough, clean burn is to be desired. Never burn in the morning unless a rainstorm is setting in.

(5) All equipment (tools, tank cars, hose, pumps) and a reserve crew should be in readiness for a fight in case the fire gives trouble.

(6) The fires should be so set (by enough men to permit rapid work) that the force of the conflagration may work toward the center of the area to be burned; they should be set on the uphill side before the downhill side, and first on the leeward side, on the flanks next, and on the windward side last. Working down a hillside in strips, or against the wind, is a good method.

(7) Slashing should be so fired that standing patches or islands of polewood or immature timber may not be killed by the slash fire. If these are killed, they merely add to the fire danger.

(8) Fires that get across the line or start outside should be put out, by the usual fire-fighting methods, especially the use of water.

PATROL OF SLASHING AFTER BURNING

Competent men should patrol the burned slashing until smoldering fires are out. In the case of spring burning any fires that could cause trouble must be put out, preferably with water, before the dry season begins. The area should be watched as long as any smoke comes from it or stray fires occur.

SLASH DISPOSAL IN THE FOG BELT

Further study and experience is necessary to determine whether in the spruce-hemlock type of the real fog belt broadcast slash burning after clean cutting is always good practice. As stated earlier spruce-hemlock slash is different in inflammability from fir slash, and the native vegetation so quickly reclothes the logged-off land in the coastal region, when there is no burning, that the fire risk returns

in a very few years to normal, or to a better condition than if the area is burned. Where slash burning is not done, however, it is imperative that doubly efficient protection be given the land for a few years until the stage of acute inflammability is passed.

In this type there is sometimes practiced what almost corresponds to selective logging—taking out the big firs and spruces and leaving a heavy stand of hemlock. These hemlocks so shade the ground that inflammability is low and temporary; to burn the slash would kill them and add greatly to the fire danger. Obviously, here broadcast burning would not accomplish its object.

SEED SUPPLY

To supplement the stored seed that may survive slash burning and to give more security against complete and permanent devastation by accidental reburns, some seed supply should be provided. As has already been pointed out, this may be either in the form of single seed trees scattered over the area or in the form of groups or bodies of uncut timber at not too great a distance.

FROM SINGLE SEED TREES

In most Douglas fir operations there are occasional large trees affected with conk to such a degree as to be of very low commercial value; on some watersheds they occur as frequently as two or three to the acre over large areas. It is somewhat of a gamble whether the merchantable material they yield would pay for the cost of "falling" and handling them. At present there is considerable variation in the methods used by operators in disposing of such trees. Operators cutting for the log market leave them standing rather than handle unsalable cull material; those cutting for their own mills are likely to "fall" them.

It is recommended that these trees of dubious merchantable value be left standing, when this can be done without seriously inconveniencing the loggers. Douglas fir is the best species to leave. Where it does not occur, the best of the other windfirm and fire-resistant trees may be left. Seed trees should always have well-formed crowns, appear windfirm, and be up to the average of the stand in size. Two trees per acre are plenty, but more may have to be left by the fallers to provide for loss in brush burning. Within 150 or 200 feet of landings and railroad tracks seed trees are undesirable.

Leaving seed trees of questionable merchantable value is a wise reforestation measure and may often be done without unreasonable sacrifice of merchantable stumpage. To have a good woodsman, like the bull bucker, designate in advance of the fallers the trees of this sort which might be left, or ought not to be cut, may actually save the operator money.

FROM ADJACENT UNCUT TIMBER

Some logging operations are so laid out that no part of the cut-over acreage is ever very far from standing timber. This may be either patches of unmerchantable trees, timber on the upper slopes of a narrow valley, or stumpage of other ownerships. Within a reasonable distance this bordering timber will help seed up the ground

during a term of years. Here single seed trees would not be essential, though always an added assurance of natural reforestation.

Where in the ordinary course of events the logged land will be far removed from standing timber, and where no defective trees are available and leaving sound trees involves an unjustifiable investment of merchantable stumpage, the operator should make an effort to so plan his logging that freshly cut and burned land may get the benefit of the seed-fall from near-by trees for at least a season or two. This can be done by logging alternate settings, a procedure now sometimes followed as a fire precaution; and also by scattering out the "sides" or logging units on separate spurs. Each cut-over tract will thus be not too remote from some green timber, through its first years at least.

TREATMENT OF THE NEW FOREST CROP AFTER LOGGING

PROTECTION FROM FIRE

The most important treatment of the new crop of timber is to protect it from fire. With effective protection against fire it will develop with astonishing rapidity into usable timber under the stimulating influence of long, mild growing seasons, abundant rainfall, and good soils.

In the preceding discussion it has been assumed that logging operators individually should protect their cut-over land as long as it is menaced by fire from their own operations. Thereafter the protection of these lands, like that of virgin forest lands, is a matter for regional cooperative action. This general protection will be considered later under the heading "Regional cooperative system of forest protection."

In addition to protection from fire, there is little that an owner need do for the growing crop. Saplings and young timber are little subject to disease or insect pests. The elements—wind, ice, and snow—will occasionally do some havoc, but the promotion of a dense, unbroken forest canopy is the best preventive of such damage.

GRAZING OF REFORESTING, LOGGED-OFF LAND

At present there is considerable grazing of cattle on logged-off valley and foothill land which is of potential agricultural character. Very commonly such land has been repeatedly burned, with the idea of discouraging tree growth as a preliminary to clearing or putting the land in pasture in conjunction with farms. With this type of land, this study is not concerned.

There has also been some grazing, both by cattle and by sheep, of cut-over land of no agricultural value. Cattle ranges are usually seeded to grasses. For sheep there seems to be enough weeds and browse to make good range without any seeding. The reasons why more of the great acreage of logged-off lands is not grazed are mostly economic and probably temporary. With increasing competition for range there is likely to be a greater use of Douglas fir cut-over land.

There has been some question whether grazing is consistent with timber growing in this region and it is therefore well to consider their interrelation. Grazing on logged lands of this region must inevitably be for a short term of years; as soon as the Douglas fir saplings and

SUCH TREES FURNISH SEED FOR THE NEW CROP

This tree was left standing by the loggers because it was too limby and "rough" to be marketed profitably

F-196016

A 10-YEAR-OLD STAND THAT HAS SEEDED IN

On land on which slash was burned promptly and under control, and which was subsequently protected from fire, seed from a few seed trees like the one in the background was sufficient to start a thrifty new stand

F—195027

A 43-YEAR-OLD STAND OF DOUGLAS FIR NOW BEING CUT FOR TIES AND LUMBER

Trees over 12 inches in diameter run 105 to the acre and up to 125 feet high. The trees towering over the main stand are survivors of a fire in 1881, and are undoubtedly the parents of the present second growth

F—195024

A 64-YEAR-OLD STAND THAT CRUISES 80,097 BOARD FEET (GROSS) TO THE ACRE

This includes only the trees 12 inches and over. Such timber will be the reward of those who cut their old-growth timber with a thought for the continuous production of full timber crops

the usual cover of underbrush form a thicket the desirable forage is crowded out and the surface becomes too brushy for profitable handling of stock. In the Douglas fir type proper that point is not reached for perhaps 10 or 15 years after slash burning. In the fog belt, dense brush springs up so soon after logging that there is little chance for commercial grazing on land protected from fire.

Under proper supervision grazing does not seem to be so detrimental as to make this use of the land inconsistent with timber production. There are in fact certain marked advantages, namely, a small annual revenue and diminution of the fire risk as a result of browsing and tramping of the herbage and brush. On exceptional areas timber growing and grazing may be obviously incompatible and here grazing should not be permitted. Sowing of tame grasses on land which is to be held for forest production seems at this writing to be neither good forestry nor good business.

A few principles in handling stock on logged-off land must be observed if the growing crop of trees is not to be injured:

No grazing until at least the second season after slash burning.
No overgrazing, either over the whole area or in spots.
Scrupulous care with fire by the stockmen.

REGIONAL COOPERATIVE SYSTEM OF FOREST PROTECTION

THE PRESENT SYSTEM

The present system of general forest protection in western Oregon and Washington is so admirable that but few changes are necessary to make it thoroughly effective. Amplifying and intensifying the present scheme, rather than changing its principles, is what is needed now.

In both Oregon and Washington the law compels the owner to protect his forest land according to certain standards. Protection over a large part of both States is directed by private organizations of the owners of contiguous tracts. Owners who do not belong to associations or do not protect their lands voluntarily must pay the State for their share, and the work is then done by the State direct or by the associations on contract. State funds and a small amount of Federal funds (under the Clarke-McNary law) supplement the protection made possible by assessments contributed by or levied on private owners.

Cooperation in the organization of field work between private, State, and Federal agencies is highly developed and leaves little to be desired. The physical organization and equipment are also excellent, and getting better every year. The lookout system, the communication system, the patrols, fire crews, auto equipment, and fire engines have all been carefully planned. An extremely effective system can be built on the present one, without fundamental alterations and with but small changes.

PRESENT EXPENDITURES FOR PROTECTION

The following statement will give an idea of the amounts now spent in the two States for protection and fire fighting by all agencies on private and State lands. The data in each case are for the whole State, as it is not easy to segregate the Douglas fir region from the

high mountain country or the region east of the Cascades, although the cost per acre is higher in the Douglas fir region than in the territory east of the Cascades. The territory within national forests, national parks, and Indian reservations is not included, since these are covered by separate, though cooperating, protective organizations. In Oregon protection is given to about 13,500,000 acres of private and State land. In the eight years 1918–1925, the average annual cost was $358,827, of which $221,941 went for prevention and $136,886 for suppression. This amounts to a charge of about 2.7 cents per acre. In Washington protection is given to about 13,800,000 acres, not including Federal lands. The average annual protection bill for the period 1918–1925 has been $400,552, including both prevention and suppression, or 2.9 cents per acre. In a very bad year (1922) over $1,000,000 was spent in protecting these lands, and even then large losses occurred.

A large proportion of the expenditures are made directly by logging companies and railroads for fighting fires. In 1925 the State bore 26 per cent of the total prevention and suppression costs in Washington and 12 per cent in Oregon; the Federal Government cooperated to the extent of 9 per cent in Washington and 6 per cent in Oregon; and the remainder came from the associations and other private sources. In years of high suppression costs the proportion of private expenditures is larger because the Federal cooperation and State appropriation are fixed and are spent mostly on prevention.

The Washington Forest Fire Association charged for protection at the rate of 2½ cents per acre in 1919, 3¾ cents per acre in 1920, 3 cents in 1921, 5 cents in 1922 (a very bad year), 3½ cents in 1923, 5 cents in 1924, and 5 cents in 1925. In Washington the present limit on the amount any owner may be assessed under the compulsory patrol law is 5 cents per acre per year. In Oregon the actual cost of protection may be assessed against the owner, with the approval of the State board of forestry.

THE PRESENT FIRE RECORD

In spite of splendid cooperation and a good working field organization, too great an acreage is burned annually. In Oregon, outside of the Government holdings, there was burned over annually on the average for the period 1918–1925, 120,000 acres, of which 37,000 acres was classed as merchantable timber and the rest chiefly as old burns and cut-over land reburned. The number of fires averaged 1,185. In Washington the average annual acreage of burns for the same 8 years was 194,000 acres, of which 22,000 acres was merchantable timber; the number of fires averaged 1,029. In each State about 80 per cent of this acreage is west of the Cascade Range, chiefly in the Douglas fir region.

The annual loss of private timber and property in the two States on account of forest fires averages close to a million dollars; some years it is very much more. It is not uncommon for one fire to cause a single operator $100,000 worth of damage.

CAUSES OF FIRES

A word here on the prevailing causes of fires may give a clew to the vulnerable places in the present prevention and suppression systems.

In Oregon, for example, where in 1924 a total of 1,888 fires outside the national forests was reported, 84 per cent were man-caused; the rest were due to lightning. In the Douglas fir region alone the proportion of lightning fires was probably even less. The following were the major sources of fires in 1924, in order of frequency: Incendiary, lightning, smokers, campers, slash burning, and clearing lands. Of the 947 fires in western Washington in 1922 (an exceptionally bad year) 174, or only 18 per cent, were directly chargeable to logging operations; but these logging-operation fires caused 78 per cent of the $862,000 worth of damage done by all fires.

NEEDED MODIFICATIONS IN THE PROTECTIVE SYSTEM

The preceding paragraphs have sketched the present protective system and the results, as a background for the suggestions now to be made for modifications necessary to keep forest land permanently productive.

CUT-OVER LAND AND YOUNG GROWTH SHOULD BE PROTECTED FOR THEIR OWN SAKE

The underlying purpose of the present protective system is the safeguarding of present values. The protection of land that a second crop of timber may be grown is now a secondary motive. Consequently, reforesting lands and lands which should reforest get a very small share of the protection funds. Cut-over land, second growth, and low-grade, scrubby stands have suffered accordingly. Fires which are not threatening merchantable timber are not fought with the vigor they might be. The intensity of protection is naturally gauged to the obvious values at stake; the object is to keep fire out of marketable timber.

If timberland owners and the State are to get the potential wealth out of logged-off land by growing timber, these lands must get their full share of protection.

THE PROTECTIVE SYSTEM SHOULD BE GAUGED TO FIT THE FIRE HAZARD

If fires are to be kept out of all classes of forest land with equal success, the fire-control organization must make more systematic study of the fire danger of various regions and tracts, and gauge the protection accordingly. Only in this way will there be assurance of the same degree of security for low-value land (like second-growth or recently logged land) as for land of greater immediate value. This may mean the spending of more money on the protection of logged-off land than of virgin forest, merely because the probability of fire starting and spreading is greater.

The fire danger or chance of a great conflagration on a given area is the sum total of a number of factors of which the most important are the actual inflammability of the material on the tract, the risk or likelihood of its catching fire, and the accessibility of the tract to fire-fighting forces.

Inflammability depends upon the local climate, the density, age, and species of the timber, the character of the surface vegetation, the topography, and several other variable conditions. It is a matter of common observation that some types of forest or surface cover burn much more easily than others. The most inflammable type in this

region is unburned slash with snags standing, and the least inflammable is second-growth timber 40 to 100 years old in dense stands. Between these two extremes is every gradation.

Topography has a very important influence on inflammability. Fire burns more fiercely on hillsides than on level ground, and on south-facing slopes than on north slopes. More intensive protection is needed in mountainous country than in flats.

Another factor that affects inflammability is the local climate. The general climate is similar in all parts of the Douglas fir region; yet there are considerable local variations in the average weather. For example, bordering the ocean and west of the Coast Range and the Olympics is the fog belt, where cold fogs common throughout the summer keep down the inflammability of the forest. From north to south in the Douglas fir region, the summer climate grows progressively hotter and drier. Again, at the higher altitudes in the Cascade Range there is a shortening of the fire season owing to the cooler temperature, greater annual precipitation, and later melting of the snows. All these factors must be taken into account in considering the relative inflammability of various areas.

Risk, or the likelihood of the starting of a fire, depends upon the proximity of railroads, logging operations, and land-clearing activities, and upon the number of campers, fishermen, and lightning storms. Since most fires are man-caused, fires are likely to increase with the increase of man's presence in a region. The number that start because of man's presence is naturally affected by the degree of care he exercises with his fires, which in turn is likely to fluctuate from year to year with changes in protection and law-enforcement methods and personnel. Incendiarism is a type of risk that is very uncertain and may occur anywhere. Were it not for lightning, it could be said that areas far removed from man's activities are least subject to the starting of fire and hence would need the least intensive protection.

Accessibility is measured by the time that must elapse between the starting of a fire and the arrival of the suppression forces. It depends upon such things as the abundance and quality of trails and roads, the natural difficulties of travel off the roads and trails, and the existence of telephone lines between the point of detection and fire fighters. Accessibility is a very important consideration in organizing the forest-protection system.

Those responsible for the protection of the region should study more critically the elements that go to make up the fire danger on each patrol district and then distribute the general cooperative fire-control moneys in accordance therewith. This is not an impossible task, even with the meager knowledge of field conditions at hand, and it is the only businesslike way of getting the most protection against fire for the money.

PREVENTIVE WORK SHOULD BE STRENGTHENED

Nowhere is the old adage about "an ounce of prevention" truer than in fire control. Fire-suppression costs and fire losses may quickly run into enormous figures; a relatively small amount of money spent on prevention will go a long way in forestalling fire-fighting bills and losses. A wise policy, therefore, is to devote so-

PHOTO BY A. M. PRENTISS

A TYPICAL LOGGING SCENE IN THE DOUGLAS FIR REGION

The railroad donkey engines, steep topography, many standing snags on the logged-off land, and the heavy accumulation of slash are characteristic

PHOTO BY A. M. PRENTISS

WHERE RISK AND HAZARD ARE EQUALLY GREAT

The high-lead yarding donkey and the loading donkey at work here are both equipped with patent spark arresters. The inflammable débris about the landing is characteristic of many operations in the Douglas fir region

much to prevention that there will be less necessity to spend money on suppression.

Prevention, direct and indirect, covers a wide field. It means educating the public to be careful with fire and to support forestry legislation and law enforcement. It means relentlessly getting after those responsible for fires. It means eliminating the causes of fires. The field of indirect prevention has been studiously worked by the present organizations with wonderful results, particularly in revolutionizing, within the decade and a half from 1910 to 1925, public sentiment toward forest fires. It is felt, however, that preventive methods must be strengthened and extended into the field of preparedness, and that as additional funds are available a good proportion should go for prevention. Such phases as the following need attention:

(1) Law enforcement, so that every section of the fire laws will be obeyed and none will be a dead letter. Violators of the law now usually go unpunished unless their act results in a fire. An insignificantly small proportion of those responsible for fires are brought to trial or punished. A special State constabulary might be assigned to this duty.

(2) Employment of a force of wardens through a longer season, so that they may be on hand for the spring and fall brush burning, and for the early and late danger seasons, and have time for preparing their districts for the fire season.

(3) Development of a closer-knit organization which will have more intensive supervision and a higher standard of responsibility. In some districts a highly developed organization like the central-dispatcher system is needed.

(4) Elimination of fire traps. Many fires may be traced to areas of special inflammability, like roadside débris, or untended railroad rights of way, settler's slashings, and logging slash. By vigorous work on the part of wardens these risks can be eliminated before the beginning of the danger season. The law in both States already provides amply for this.

Many other features of preparedness which need strengthening might be mentioned, such as the building of more lookouts, trails, telephone lines, and firewarden tool caches, but the above illustrate for the purpose of this bulletin what must be done before safety is given to our forest land.

MORE MONEY FOR GENERAL PROTECTION

Effective protection extended to cut-over land and better prevention everywhere inevitably mean that more money must be available. The present funds available for forest protection are not enough to give the degree of security desirable for the growing of successive crops of timber, no matter how wisely they are spent. More money must come from somewhere before timber growing is on a substantial basis in the Northwest.

It is rather bold to attempt an estimate of the amount of money which ought to be spent for forest protection. No amount of money could reduce the fire losses absolutely to zero, for accidents will happen anywhere sometimes. On the other hand, since practically all fires in the Douglas fir forests are man-caused, there would be little need for an expensive fire-prevention and fire-suppression force

if the public and all users of the forest were trained to be as careful with fire in the forest as they would be in a powder factory.

In time it is hoped that persistent propaganda and direct preventive measures will have the effect of diminishing the need for a big protective organization. But for the present, money spent liberally on saving what virgin timber and second growth there is and on starting other lands to reforest is well spent both for the owner and the commonwealth. If the recommendations made above are followed, especially those for better law enforcement, better slash burning, and more care with fire in logging, it will not be necessary to spend a great deal more money on general fire control. The present system in western Oregon and Washington probably costs, for the area actually protected, about 3 to 3½ cents an acre a year.[3] Add to this another cent an acre effectively spent on direct prevention as outlined above and forest investments both in young and old timber would be reasonably safe.

There is a large acreage not now given regular protection (property of local residents, for example) which should come under the system and there is a still larger area being protected which is not paying its share of the cost (cut-over land which is not considered a menace or which the State foresters can not assess for compulsory patrol). Thus some owners not now paying their share for protection should do so. If all owners of forest land were paying their proportionate share, the system could be made more effective even without any increase in the present assessment rate. The workings of the existing compulsory patrol law should be extended.

MODIFICATION OF STATE FIRE LAWS

The fire laws of the two States are generally satisfactory for the Douglas fir region. Modification of the present law is less important than better enforcement. There are some minor improvements in the law which might be made, but it is not the province of this bulletin to suggest the legislative enactments necessary to carry out the various suggestions made herein. It is its province to treat of the principles that underlie continuous forest production rather than the economics or machinery of applying these principles. Other agencies are giving consideration to the details of needed legislation.

RETURNS AND COSTS OF MINIMUM MEASURES

EXPECTED FUTURE YIELDS

Studies of the growth and yield of Douglas fir in western Oregon and Washington furnish a reliable basis for the prediction of probable returns from timber growing in this region. These studies were confined to normal, fully stocked stands, those where all available space is being utilized by living trees. Such methods as have been recommended in the preceding pages should result in fairly successful regeneration and growth. Some stands will probably not be fully stocked; there will be holes and thin places in the forest; now and then there will be nonreforesting areas which continue to lie unpro-

[3] This is an average figure. In certain years some individuals and associations have spent many times this amount, but that was because their protective efforts were not successful and they had enormous fire-fighting expenses.

ductive. In such stands the number of trees per acre and the yields under minimum measures will not be up to those of so-called normal, fully stocked stands.

The tables which follow [4] are based on measurements of completely stocked forests, and in using them for a forest which is not fully stocked a discount must be made proportional to the blanks and understocked patches. Also if there is delay in securing the restocking of the area that delay must be allowed for, as the tables are based upon the age of the trees composing the new crop and not upon the number of years since the former crop was cut.

In the yield studies referred to five classes of land were recognized, according to their ability to grow timber—excellent, good, fair, poor, and very poor. The last two classes are uncommon and are of importance in only a few restricted portions of the Douglas fir region. Accordingly, in the following tables data are presented for only the three best qualities of land.

In Table 1 is indicated the approximate number of trees of all sizes to be found at various ages on 1 acre in a fully stocked stand of Douglas fir. Satisfactory but not ideal stocking may be had during the first decades with somewhat fewer trees to the acre than are indicated in this table. To get full use of the ground space and to produce a second crop of fair quality it is desirable that by five years after the slash burn there be at least 500 established seedlings to the acre. If by five years after burning cut-over land has less than 250 established and well-distributed seedlings per acre, it can not be considered to be reforesting in accordance with the standards set in this bulletin.

TABLE 1.—*Total number of trees per acre 2 inches in diameter and larger in fully stocked stands*

Age of stand	Quality of land		
	Excellent	Good	Fair
Years	*Number*	*Number*	*Number*
20	571	880	1,460
40	240	385	585
60	138	288	337
80	97	159	232
100	75	123	184
120	63	101	152

In attempting to answer the common question, "How long does it take to grow a crop of timber?" it may be observed that there are many tie mills in this territory operating in timber less than 75 years old; one mill is known to be operating exclusively in 43-year-old timber and getting a satisfactory cut. On poor sites it would take very much longer to produce the same size and grade of logs. Table 2 shows the yield in board feet of fully stocked stands considering only those trees of the final crop (not thinnings) which are 12 inches and larger in diameter. Close utilization to an 8-inch top is assumed, and no allowance has been made for defect or breakage.

[4] Tables 1, 2, and 3 are from a manuscript report by Richard E. McArdle, summarizing the results of an exhaustive study of the growth and yield of Douglas fir conducted by the Pacific Northwest Forest Experiment Station.

TABLE 2.—*Yield per acre in fully stocked stands of Douglas fir, gross saw timber volume, of trees 12 inches and over, Scribner rule*

Age of stand	Quality of land		
	Excellent	Good	Fair
Years	*Board feet*	*Board feet*	*Board feet*
20	400		
40	24, 400	11, 900	4, 500
60	62, 000	42, 800	23, 800
80	92, 500	76, 000	45, 700
100	115, 100	90, 400	62, 800
120	131, 100	105, 100	75, 000

Expressed in cubic feet or in cords or as linear feet of round timber, the possible yields would be even more promising, for the volume of small timber expressed in board feet is misleading. The volume, in cubic feet, of the stems (exclusive of bark) of all the living trees in the stand (but not thinnings) is given in Table 3.

TABLE 3.—*Yield per acre in fully stocked stands of Douglas fir, gross cubic-foot volume, of all the trees*

Age of stand	Quality of land		
	Excellent	Good	Fair
Years	*Cubic feet*	*Cubic feet*	*Cubic feet*
20	1, 830	1, 550	1, 250
40	7, 500	6, 550	5, 250
60	12, 500	10, 860	8, 700
80	16, 350	14, 220	11, 350
100	19, 140	16, 610	13, 270
120	21, 090	18, 340	14, 600

In view of the advancing values of standing timber and the prices now prevailing in the older forest regions, it seems reasonable to expect that by the time the next crop of Douglas fir is merchantable its stumpage value may easily be three times present values. This should be taken into account in converting volume yield to a money basis. Also, the yield from thinnings, when it is economically possible to make them, will give a substantial addition to the prospective returns.

COSTS

In the preceding pages requirements essential for keeping forest land reasonably productive have been recommended, but only after a thorough weighing of the cost of each requirement, and with the intent to classify as essential only those which will give the largest benefits for the money invested. This bulletin would not be complete without some attempt to state the cost of these measures.

Estimates of these costs are very likely to be misleading, so varied are conditions in different districts. It may cost much more on one tract to reach the standard degree of security against fire than on another. The estimates here given, therefore, should be considered as very broad averages for the region as a whole. They are the estimated costs of carrying out the above-recommended requirements

in excess of the cost of operation now incurred by the average timber owner or by the average efficient operator, either at his own volition or in compliance with law. Where an operator's expense for one item may be more than the average, for another item it may be less.

Many of these measures will repay the operator in added security to his timber and logging investment, but if they are measures which the average operator is not now taking, they have been considered here as chargeable to reforestation.

CARE OF THE VIRGIN FOREST

For protection against fire.—An increased expenditure for general cooperative forest protection (to be spent in fire prevention, thereby saving on suppression cost), amounting to about 1 cent per acre for lands already assessed. In order to protect the virgin forest, protection in addition should be extended to cut-over lands not now fully assessed or not assessed. This will likely be financed partly by public appropriations.

TREATMENT OF THE FOREST DURING LOGGING

For direct protection.—(1) Fire chief (expense in addition to present expenditures). From 4 to 15 cents per thousand feet logged during the summer season, depending on the size of the operation, or 2 to 7 cents per thousand feet for the entire year's cut, averaging 3½ cents.

(2) Organization and discipline of crew. Nothing.

(3) Firemen, watchmen, etc. Ten cents for each thousand feet logged during the summer season, or about 3 cents per thousand feet logged during the entire year.

(4) Keeping in touch with weather prediction service. No material cost to operator.

(5) Spark arresters. Already required, no extra cost.

(6) Clearing around donkey settings and sprinkling about donkey engines. The cost is trifling and should not amount to over 0.5 cent per thousand feet logged during the summer, or 0.25 cent per thousand feet of the year's cut.

(7) Having fire-fighting tools handy. The cost is inconsiderable.

(8) Water system. This inevitably will vary greatly from operation to operation, depending on chances for water, on topography, and on how much logging is done during the fire season. A charge of 2.5 cents per thousand feet of the entire year's cut should cover the expense of this equipment over and above the expense necessary to get water for donkey operations. On some jobs this requirement will be less; on others, more.

For fireproofing cut-over land.—(1) Burning slash. Now required by law. Careful burning and more frequent burning will probably cost more theoretically than the present wholesale haphazard method, though it may often save big expense and loss in the long run. One dollar per acre, or 2.5 cents per thousand feet logged should cover the extra attention to this work.

(2) Closer utilization. No extra expense. In some camps attention to this detail will mean additional profit.

(3) "Falling" snags. The cost of this will be exceedingly variable. Where there are few snags or where they are felled under present practice there will be no additional charge. For "falling" snags that still stand after logging and are wholly unmerchantable the cost will probably range from a few cents to $5 or more per acre, with an average of $3.25 for the Douglas fir region at large, or 8 cents a thousand feet logged.

(4) Burning débris resulting from right-of-way clearing, etc. Usually done as a matter of insurance, but if done thoroughly enough to make the rights of way serve as fire lines, it will cost extra—possibly on the average 2 cents for each thousand feet of the year's cut.

TREATMENT OF THE NEW FOREST AFTER LOGGING

For protection against fire.—Same as for the virgin forest, covered by the general cooperative protection scheme already estimated.

For other considerations.—No expense unless there is commensurate return.

SUMMARY OF COSTS

It is estimated that compliance with the essential requirements for continuous forest production recommended in this bulletin would cost on the average, over and above present customary expenditures, (1) 1 cent an acre for each acre of forest land for general protection and (2) 22 cents for each thousand feet of logs cut in the region.

In other words, the expenditure in the cause of reforestation of 1 cent more an acre for general protection from fire on all forest land than is spent now and of 22 cents more per thousand feet at the time of the logging operation would reduce the annual fire toll of about a million dollars to within reasonable bounds, would greatly reduce fire-fighting bills, would allow new forests to replace those cut, and would do away with the appalling loss in private wealth and public welfare occasioned by the idleness of hundreds of thousands of acres of fire-scourged stump land.

This is not the place to discuss how well it will pay the individual to make this investment of 1 cent an acre and 22 cents for each thousand feet cut. That would involve a prediction of future stumpage values, interest rates, stability of ownership, taxation, and the like. It is for each owner to decide for himself what his business policy in the handling of his land should be, after studying the facts, learning what the returns may be and what the costs, and applying these data to his own property.

SUPPLEMENTARY MEASURES FOR INTENSIVE TIMBER GROWING

Certain owners are not satisfied to realize only a part of the productivity of their lands, such as may be attained by the minimum measures discussed in the preceding pages, but wish to grow full crops of timber on their cut-over land. They are interested in what more intensive timber-growing measures may accomplish. Some private operators in the Douglas fir region are already putting into effect practices that are more intensive than those described in the preceding pages, and as virgin stumpage becomes scarcer and second-growth stumpage attains a higher value, it is inevitable that the

profitableness of intensive timber growing will become more apparent and its practice more general.

The State and the Federal Governments can afford to practice, and the latter is now practicing, measures that the private owner rightly or wrongly may not as yet feel he can afford to undertake. The forest management on the national forests of this region goes further than the essential measures recommended in the foregoing section.

It is the object in the following pages to outline very briefly forest practices supplementary to minimum measures which are necessary to produce full timber crops. Some of them are now in effect on private lands or on the national forests; others are technically desirable but can be put into effect only as economic conditions justify them. What may seem impracticable to-day may be regarded as highly profitable 5 or 10 years from now.

These measures will give greater assurance of continuous crops and larger yields than will the primary measures alone, but they will cost more. Even in the matter of expense, however, intensive management designed to produce both the largest crops and the best quality crops has certain obvious advantages. The two major items of expense in forestry for the private owner in this region are taxes and protection from fire. Both of these expenses remain the same whether the timber-growing measures be crude or intensive and the crop partial or full. An owner contemplating continuous production will do well to determine how much he is justified in spending to establish the new crop, i. e., what intensity of management on his particular operation will yield maximum returns, and whether it will not pay him better to strive for maximum production than to be satisfied with the results that the simplest measures will give.

Intensive forest management to secure full crops of timber will not be fundamentally different in method from the minimum measures. The difference is chiefly one of degree. All the measures recommended as primary are equally important for intensive timber growing gauged to attain maximum production. They need, however, to be intensified and supplemented.

Under both crude and intensive forest management in the Douglas fir type clean cutting with broadcast burning of slashings is recommended. Fire control will always be a big part of any timber-growing activity in this region. Douglas fir will be the principal species sought for the second crop except in the spruce-hemlock belt and in the upper-slope types.

Forestry is still so new in the Douglas fir region that there has not yet been time to demonstrate all the refinements of intensive practice. Further research is necessary, particularly in such matters as slash disposal in the fog belt, the control of the mixture of species, the making of thinnings, and the source of the seed that must be depended upon for Douglas fir reproduction. The following recommendations must be taken with the understanding that the exact technic of intensive silviculture will be much improved through further study and experimentation.[5]

[5] This discussion is limited to a consideration of methods of cutting and regenerating old-growth virgin timber, with which the logging industry will be occupied chiefly for some time. The methods to be employed in harvesting second growth and providing natural reproduction thereafter is another matter, which can be left until the industry is more concerned with the exploitation of younger timber, as it will be in another two or three decades.

TECHNICAL PLAN OF MANAGEMENT

An owner undertaking to handle a tract of forest for continuous timber production and for getting the maximum returns from the land should make a systematic plan of management, based on technical studies of the property. The land itself should first be classified, in order that each acre may be devoted to its ultimate highest use, the agricultural land to be sold for that purpose and the forest land to be held for timber growing. It is next important that he know what continuous sustained production the forest land is capable of yielding decade by decade. To this end the tract should be cruised and an inventory made of the present growing stock, both virgin and immature. Studies of growth should be made to determine the yield possibilities of each watershed, and thereby enable the owner to make his financial plans for the permanent operation of the property. Probably a good topographic and type map should be made to assist in carrying out the orderly exploitation of the crop and as a graphic basis for preparing the management plan.

The management plan should point out what parts of the stand should be cut first, because of the maturity or marketability of the timber, and what areas should await better utilization. In prescribing an orderly logging program consideration should also be given from the engineering viewpoint to laying out the operation in such a way that the tract may be given the best protection against fire. A well-thought-out scheme for fire control may well be a definite part of the management plan.

On the national forests, management plans are being prepared as fast as watersheds or working circles are brought under intensive use. They are equally important for private holdings. The nature of such plans will vary with the size and character of the particular tracts, and the desires of the owners. Their preparation is a task wherein experts trained for this sort of work are needed.

DIRECT PROTECTION AGAINST FIRE

The requirements for protection against fire are of necessity set so high for minimum practice that the same requirements ought to give results satisfactory for intensive forest management. In both instances the system is gauged to prevent man-caused fires and to stop all fires that do start before they become serious. In fire control there should be no halfway measures. The present cooperative system of forest protection for the region at large needs strengthening along the lines already suggested. If this is done and fire is controlled during logging, present investments can enjoy the reasonable security against fire which is necessary to give the growing of continuous crops of timber economic stability. Many specific precautions have been recommended for logging operations. If all of these are enforced to the letter the great curse of timber growing—fire escaping from slash-burning and logging operations—should be removed.

Other precautions might be suggested for certain cases. For example it may be both necessary and expedient on some large tracts to wholly exclude the public during the fire season. If the risk of fires from campers, fishermen, hunters, and berry pickers can not be controlled in any other way, the timber owner must have recourse

to prohibiting the entrance of the general public upon his lands, to protect himself against the small minority who will not be careful with its tobacco and camp fires.

An effective but rather heroic measure for preventing fire from being started by logging operations is to suspend all logging during the acute fire season. This is already being done by a few operators when the fire season is coincident with dull markets or they can accumulate enough logs in the spring to stock their mills through the summer. It is likely this practice will become more common, and it has much to commend it purely as a measure of business economy.

INDIRECT PROTECTION AGAINST FIRE, OR FIREPROOFING LAND

Considerable emphasis has been placed upon the desirability of "fireproofing" logged-off land, or putting it in such a condition that it will be less subject to fire, and fires will be easier to control. This involves various measures other than direct protection, such as snag "falling," close utilization, slash disposal, and clearing rights of way. There is almost no limit to the work that might be done to make reforestating areas less inflammable. The measures already recommended as minimum will by no means leave the land immune to fire; they give only the probability of reasonably satisfactory reforestation. An owner who wishes to grow full crops, to lose none of his second growth by accidental fires, and to have it unthinned and unscarred by spot fires, is warranted in taking more intensive steps at the time of logging to fireproof his logged-off lands to make them really safer for reforestation. This will mean a larger initial investment, but it will yield dividends in fuller crops and lower fire-prevention and fire-fighting bills.

Each owner should study his particular problems—the local inflammability, the human risks, the general hazard to which his lands are subjected—and then decide how far he must go to attain the degree of security he ought to have as a business proposition. There are several ways in which fireproofing may be intensified, any or all of which may be advisable, depending upon the condition of the tract in question:

(1) Snag "falling." It is assumed that all snags 20 inches or more in diameter will come down as a minimum requisite. It is still safer to have them all down. This recommendation includes "falling," prior to slash burning, those understory small hemlocks and other small trees that are not worth logging, have no value as seed trees or for the future crop, and are sure to be killed but not consumed by the slash fire, and so to add to the inflammability of the area.

(2) Leaving natural firebreaks of uncut timber along the creeks where, as is commonly the case, there is a strip of fire-retardant and unmerchantable hardwoods—maple, alder, cottonwood, willows, and swamp undergrowth. If such areas are not logged through they may function very successfully in partitioning off a fire. The coniferous trees in such strips, if any, will furthermore act as seeders, obviating the necessity for reserving isolated seed trees on the logged land near these strips.

(3) Fire-line construction. Firebreaks along rights of way or ridges, which break up a tract into units for better protection, are good insurance. They should be a consideration in every plan for intensive management. They serve also as routes of travel. Fire lines are of course useless unless they are kept open to travel, that the fire patrols may get quickly to all parts of the tract. The planting of fire-retardant hardwoods along the fire lines as a spark or flame screen has also been proposed and is being tried.

PROVISION FOR ASSURED REFORESTATION THROUGH SEED TREES OR PLANTING

It is not expected that such minimum measures for securing natural reseeding as are recommended earlier in this bulletin will effect complete stocking in many instances. Those simple measures rely upon seed stored in the ground and surviving the slash burn, seed blown from near-by standing timber, and seed from defective trees left standing. The chances are good that with successful slash disposal and fire control most areas will be reseeded fairly satisfactorily through one agency or another or all together. But these crude measures can not be expected to be uniformly successful in good seed years and bad, to provide against loss of all natural reforestation in the event of second fires, or to result in a complete stand of new growth on every acre.

For owners who propose to practice intensive timber growing and get full crops from their land two methods of supplementing and assuring reforestation are possible: (1) Leaving more seed trees; (2) planting the failed areas. In some regions these supplementary provisions will be more necessary than in others, and their cost will vary considerably from one tract to another. Whether one or the other is used will depend upon circumstances—the character and value of the seed trees that are available for leaving, the security of the area against second fires, and the financial policy of the owner. The decision as to how to secure maximum reforestation at minimum outlay is thus a technical question, involving study of local conditions, which can best be made by an experienced forester.

LEAVING ADEQUATE SEED TREES

In addition to leaving unmerchantable Douglas firs with good crowns for seed trees, as already recommended, intensive forest management should be prepared to leave seed trees of merchantable value where there are not other sufficient sources of seed. This is, of course, provided that the stumpage investment thus involved is not greater than would be the cost of planting to attain the same result. It must be remembered that, as a 44-inch Douglas fir has some 3,000 board feet in it, sound seed trees of even this size involve a large investment. Where the proper kind of seed trees are available and they do not represent an investment out of proportion to the good they can do, the aim should be to leave two per acre. To get this number more may have to be designated before logging, for the operation and the slash burn will inevitably destroy some. They should be trees of seed-bearing capacity, of a size to withstand the logging operation and the slash burn, likely to be windfirm, and with healthy crowns, whether their boles are of good merchantable character or not.

They should be spaced a fairly uniform distance apart except that it is safer (for both the trees and the loggers) to leave none within 200 feet of landings or railroad tracks. Douglas fir is the preferred species for seed trees wherever obtainable. Its associates are less likely to withstand fires and wind.

PLANTING THE FAILED AREAS

Where there are no adequate seed trees to leave or where their value for saw logs is greater than the cost of planting, it will be better to plant up artificially the areas that may fail to reforest naturally. In other words, rather than leave several dollars worth of good trees on every acre it may be a better plan to plant the portions of the area that perchance fail to reforest naturally. Planting is, however, a rather expensive operation and is not recommended as a general practice for this region. It will be desirable mainly for restocking spots of logged-off land where natural seeding fails because of lack of a seed supply or repeated fires. Where the seed trees would not be windfirm (as in some spruce-hemlock country, for example) and where natural reproduction can not be expected from either stored seed or from seed blown in from the side, there is no alternative to planting. Planting is also particularly applicable where it is desired to introduce into the stand a larger proportion of some species, such as Sitka spruce for pulp wood on the hemlock land of the fog belt.

It is expedient to defer planting until it is apparent that an area will not reseed naturally, and one can be sure that an area will not reseed only after a seed year or two have passed (except in the case of repeated burns) and a careful scrutiny of the ground has been made.

Where planting is relied upon and no seed trees are left, the entire investment in planting may be lost through an accidental fire and have to be repeated. This is a consideration in choosing between the planting and seed-tree methods, for seed trees are less liable to be so lost.

Planting nursery-grown trees rather than direct seeding is recommended because sufficient seed is not likely to escape the birds and rodents unless an extravagant quantity is used. Planting of wild stock is not recommended, as this stock does not stand transplanting as well as nursery-grown trees, and it is expensive to collect.

Where Douglas fir is planted the surest stock to use is 2-year-old, once-transplanted trees. Such stock can be grown in quantity for about $7 per thousand. Two-year old, untransplanted stock will be considerably cheaper and may have a place in some planting jobs. A spacing of 8 by 8 feet (680 trees per acre) is now used by the Forest Service. The cost of actual planting varies greatly with the rockiness of the soil, the topography, and the amount of brush and down logs on the ground. Good work is likely to cost about 0.75 cent to 1 cent per tree, or $5.10 to $6.80 per acre. This makes the total planting cost in average Douglas fir country about $14.50 to $17 per thousand 2-year-old transplants, or, roughly, between $9.50 and $12 per acre, exclusive of transportation charges from nursery to field.[6]

[6] Further details concerning the technic of artificial reforestation are given in reports of the extensive experiments by the Forest Service in this region, not all of which have as yet been published.

RECLAIMING DENUDED LANDS BY PLANTING

The above discussion has to do with planting as a supplementary means of getting reproduction after logging. There is another field for planting, namely, putting into productive condition the larger areas which have been denuded by fire or logging, or both. There are half a million acres of such land in this region, three-quarters of it in private hands. This land, if left to itself, will become reforested only by the very slow process of seeding-in from the sides or from the few trees, many not yet of seed-producing age, which occur here and there.

In addition to this denuded land is the still larger acreage that is now partially tree covered or will become forested if only given protection from fire, but which is a long way from producing full crops. It is either irregularly or inadequately stocked.

Intensive management would strive to restore these denuded lands or poorly stocked lands to full productivity as rapidly as possible, supplementing by direct planting of nursery-grown trees what protection from fire alone can not do. Owners who are putting their forest property into full productive condition may well give attention to this class of land. Detailed examination on the gound is very important to determine what the status actually is and what nature is likely to do unaided in restoring the land to forest.

CONTROL OF THE MIXTURE OF SPECIES IN THE NEW CROP

A part of the art of forestry is to get a desirable mixture of species in the new crop. That is one way of realizing the maximum-value production from the property. Where planting methods are used on completely denuded land, the desired mixture can be obtained very readily. With natural reproduction it is not so simple, but further study will undoubtedly show possibilities for regulating the mixture to some degree by methods of brush disposal. This is a particularly important problem in the fog belt, where spruce is the preferred species, and where there is a tendency for the new crop to be too largely of the less desired hemlock or, temporarily, of alder. The problem is mentioned merely to indicate one phase of intensive management that the forester must consider in some localities, and one that demands research.

THINNING THE GROWING CROP

In the discussion of minimum measures it was shown that after the new crop is started little need be done except to protect it from fire. However, as forestry becomes more intensive with changing economic conditions, closer utilization of the forest is going to be possible. One such phase of closer utilization is the thinning of immature stands. This is a practice which is highly recommended where there can be found a use or a sale for the material so cut.

It is well recognized that many more trees start than have any chance of reaching maturity. It is common to find 10,000 seedlings per acre, while a normal second-growth fir stand at 20 years has about 900 trees per acre, at 50 years about 300 trees (of all sizes), and at 100 years 125.

Properly executed thinnings will materially accelerate the growth of the stand, by giving each tree the ideal amount of growing space. Under intensive management it is entirely possible to get as much volume of timber out of several thinnings as an unthinned stand would yield at maturity. This phase of tending the growing crop is a most important field for the forester's art and should not be overlooked by the owner who is studying the possibilities of intensive forest management.

The trees that die, fall over, and rot might just as well be cut and utilized before they die. Those from the 25 or 30 year old stand would yield poles and wood; those from the 50-year-old stand would make cordwood, ties, mining timber, piling, and even small saw timber. The amount of material in second-growth stands which is now going to waste and might be utilized by making thinnings is enormous. An instance is at hand where one portion of a 42-year-old stand yielded 8.78 cords an acre in casual thinnings in 10 years, and at the end of that time had as much volume (84.7 cords per acre) as the unthinned portion, and in trees of larger diameter.

Already a kind of thinning, though without technical care for its effect on the growing crop, is being practiced in some very accessible young stands, as on farmers' wood lots. The time is not far distant when it will be economically profitable in this region to make a general practice of cutting the superfluous trees out of immature stands which are reasonably accessible.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

June 1, 1927

Secretary of Agriculture	W. M. JARDINE.
Assistant Secretary	R. W. DUNLAP.
Director of Scientific Work	A. F. WOODS.
Director of Regulatory Work	WALTER G. CAMPBELL.
Director of Extension Work	C. W. WARBURTON.
Director of Information	NELSON ANTRIM CRAWFORD.
Director of Personnel and Business Administration	W. W. STOCKBERGER.
Solicitor	R. W. WILLIAMS.
Weather Bureau	CHARLES F. MARVIN, *Chief.*
Bureau of Agricultural Economics	LLOYD S. TENNY, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Forest Service	W. B. GREELEY, *Chief.*
Bureau of Chemistry	C. A. BROWNE, *Chief.*
Bureau of Soils	MILTON WHITNEY, *Chief.*
Bureau of Entomology	L. O. HOWARD, *Chief.*
Bureau of Biological Survey	PAUL G. REDDINGTON, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Bureau of Dairy Industry	C. W. LARSON, *Chief.*
Office of Experiment Stations	E. W. ALLEN, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*
Federal Horticultural Board	C. L. MARLATT, *Chairman.*
Insecticide and Fungicide Board	J. K. HAYWOOD, *Chairman.*
Packers and Stockyards Administration	JOHN T. CAINE III, *Chief.*
Grain Futures Administration	J. W. T. DUVEL, *Chief.*

This bulletin is a contribution from

Forest Service	W. B. GREELEY, *Chief.*
Branch of Research	EARLE H. CLAPP, *Assistant Forester, in Charge.*

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
15 CENTS PER COPY

▽